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THE DEVELOPMENT OF AN ELECTRONIC ANALOG FOR THE STUDY OF THE ECONOMIC SYSTEM OF THE UNITED STATES

A THESIS

Presented to

the Faculty of the Graduate Division

by

Thomas L. Newberry, Jr.

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Industrial Engineering

Georgia Institute of Technology

May, 1958

THE DEVELOPMENT OF AN ELECTRONIC ANALOG

FOR THE STUDY OF THE ECONOMIC SYSTEM

OF THE UNITED STATES

APPROVED:

Date Approved by Chairman: _____

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SUMMARY

The purpose of this study was to develop a dynamic electronic analog model of the United States economy. The objectives of the model were as follows:

(1). To determine if forecasting of economic situations could be performed without extensive mathematical analysis.

(2). To obtain a method of evaluating alternative economic proposals on a national level.

The first part of the study was concerned with developing the proper block diagram relations of the gross national product and the related spending and income items. An electronic analog diagram was developed from the block diagram.

There was a need for much reduction of data. Graphical analysis with the aid of simple mathematics was used to determine the proper constants for the analog. The suggested model was then programmed into the Berkeley Model 1032 Analog Computer. Revisions in settings were made while conducting certain circuit analyses. The series of experiments conducted in this study were divided into two parts--the first series for the purpose of establishing a valid model, and the second series for the purpose of making actual forecasts and the study of interactions. The first series of experiments

was performed and analyzed. The results of these experiments were used in the development of the second series of experiments. During the latter series, various forecasts were made and interactions studied. The results of these series of experiments consist of graphs which have been plotted directly by the analog computer.

The results obtained were favorable in that they indicated a model which could portray the characteristics of a macro-economic system could be developed by the means presented here. An incidental observation was that dynamic models could possibly be used extensively as an aid in the class room study and analysis of non-physical systems.

It is recommended that this model be improved and that more analyses of similar nature be undertaken with the hope that we will some day understand economic fluctuations and their cause-and-effect relationships quantitatively.

CHAPTER I

INTRODUCTION

Throughout history industrial organizations have been subject to periodic fluctuations such as over-employment, under-employment, over-capitalization, under-capitalization, and other maladjustments. Problems of economic stabilization and prediction have been attacked with little success. That economic systems, both regulated and unregulated, have a cyclical nature is generally recognized. However, there is a definite need for a quantitative understanding of economic systems. It is well known that until one is able to measure cause-and-effect relationships, few constructive conclusions can be reached about them.

Only in the past 25 years has econometrics become a tool of science. The progress made in this field during that time has been most remarkable. This rapid advancement in econometrics has been aided by the tremendous capacity of digital and analog computers, which have only in the past decade been developed commercially. Consequently, data can be reduced and analyzed--data which years ago would not have been usable. Both of these types of computers can be used as a supplement for the other in economic application and research.

It was the purpose of this study to develop an electronic analog

of a macro-economic system, in this case the United States economy. This electronic analog should aid in forecasting and should enable rapid quantitative evaluation of alternative economic proposals without the need for extensive mathematical analysis. The interaction of various factors upon others are to be observed and studied. It is hoped that the model derived from this research study will be helpful in a better understanding of the use of analog computers in the analysis of economic and other non-physical systems.

Macro-Economic Forecasting

There are two types of economic situations, micro-economic and macro-economic. A micro-economic situation involves a small segment of the economy, such as a private business. A macro-economic situation is one which involves the economy as a whole. It implies the use of aggregated variables. Forecasting the national debt, gross national product, or producers' durable equipment would be examples of macro-economic forecasting.

Leads and Lags. --Some of the most interesting undertakings in forecasting have been the study of the economic phenomena known as leads and lags. This study of leads and lags centers around the possibility that a certain sequence of events will exhibit a degree of regularity from cycle to cycle. The method of approach in determining this relationship is to investigate past business cycles with a view to obtaining certain

time relationships between indicators and the item of interest. Harvard University attempted such a program which failed and was discontinued in 1941.[1] This failure was attributed to their study of leads and lags being confined to only three indicators: stock prices, bank debits, and short-term interest rates. In this case, a weak theoretical framework led to an unrealistic model.

The National Bureau of Economic Research, under the direction of Dr. G. H. Moore, successfully forecast the 1953-1954 recession. Over eight hundred statistical series were analyzed for the period 1919-1938 in the hope of finding series which had cyclical swings matching general business conditions. Twenty-one series were selected, of which some moved ahead, some moved with, and others moved behind the general cycles.[2] There is an implicit assumption that leads and lags constitute the entirety of the theoretical framework. It is expected that this technique, when sufficiently refined, will aid economic forecasting. With the use of digital computers for reducing data, many tasks which were considered previously as insurmountable may now be programmed for speedy and accurate solutions.

Regional Cycles. --Another approach at forecasting has been that of

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[1] E. C. Hald, Business Cycles, Cambridge, Mass., The Riverside Press, 1954, pp. 354-356.

[2] S. J. Maisel, Fluctuations, Growth, and Forecasting, New York, John Wiley & Sons, Inc., 1957, pp. 400-407.

considering industrial areas as separate entities rather than combining them with other areas and studying the national pattern.[3] Six industrial areas--Los Angeles, San Francisco, Chicago, Detroit, Cleveland, and Pittsburgh--were studied extensively for over seventy years with regard to industrial employment, department store sales, power sales, and bank debits. The reasoning here is that business cycles are characteristic of urban masses where there is a concentration of people and industrial operations. Variations in business activities are transmitted from business to business, and area to area in the complex relationships between business firms. This approach appears quite logical. At the time of this writing, the United States is in a period of general business recession. While some areas have not as yet been affected, others have felt the pinch of the recession since the latter part of 1957. The objectives of the study referred to above were to discover similarities or differences in the timing, duration, and pattern of business cycles in the six selected industrial areas and to identify these causes of divergent cyclical reaction.

The conclusions drawn from the above investigation revealed that there were definite variances between cycles in different industries and between cycles in different areas. It cannot be assumed that regional

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[3]Philip Neff and Annette Weifenbach, Business Cycles in Selected Industrial Areas, Los Angeles, University of California Press, 1949, p. 5.

economic factors will behave as the national economy does.

Use of Models in Macro-Economic Situations

A scientific model is a representation of some subject of inquiry and is used for purposes of prediction and control. The primary function of a scientific model is explanatory rather than descriptive. It is intended to facilitate an understanding of how changes in one or more aspects of the model may affect other aspects or the whole.[4] The two types of models which have been used in the study of economic systems have been the analog and the symbolic. An analog model represents one set of properties by another set of properties. In a symbolic model, the components involved are represented by symbols--usually mathematical or logical in nature. All models are either static or dynamic. A dynamic model, as opposed to a static model, involves time. Only dynamic models are of interest for the purposes of this study.

Dynamic Models.--The following dynamic models were consulted before the development of the electronic analog described in this study:

(1). Burns' and Johnson's Analogue Model of the Flow of Money in the United States Economy.[5] In this model money payments are

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[4]C. W. Churchman, R. H. Curkoff, E. L. Arnoff, Introduction to Operation Research, New York, John Wiley & Sons, Inc., 1957, pp. 157-168.

[5]R. K. Burns, and H. W. Johnson, Understanding Money and Banking, Chicago, University of Chicago, 1953, pp. 23-29.

shown flowing in a circle, consumers on one side and producers on the other side. The model is progressively added to until it contains savings and investment, then cash holdings and lending; and finally government economy with its taxes is shunted into the stream of flow.

(2). Hald's Analogue Model of the Flow of Money in the United States Economy.[6] This analogue depicts graphically the direction in which money flows in our economy with regard to consumers, producers, markets, banks, the government and foreign countries. This diagram also shows where money can be temporarily removed from the flow.

(3). Robinson's Analogue Model of the Flow of Income and Spending in the United States.[7] This analogue shows the relationship of gross national product, national income, etc., with regard to the flow of money (See Figure 1). The basic idea for the model used in this study was obtained from this source.

(4). The Clark Symbolic Model of the American Economy.[8] This linear symbolic model employs six endogeneous variables and four exogeneous variables, using six equations. The endogeneous variables are the values of these variables at some time prior to that under

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[6]Hald, op. cit., pp. 274-280.

[7]Robinson, Morton, and Calderwood, An Introduction to Economic Reasoning, Washington, Brookings Institution, 1956, pp. 231-239.

[8]Joseph Krol, Unpublished Class Notes for Course in "Advanced Engineering Economics," Georgia Institute of Technology, 1957, pp. 60-62.

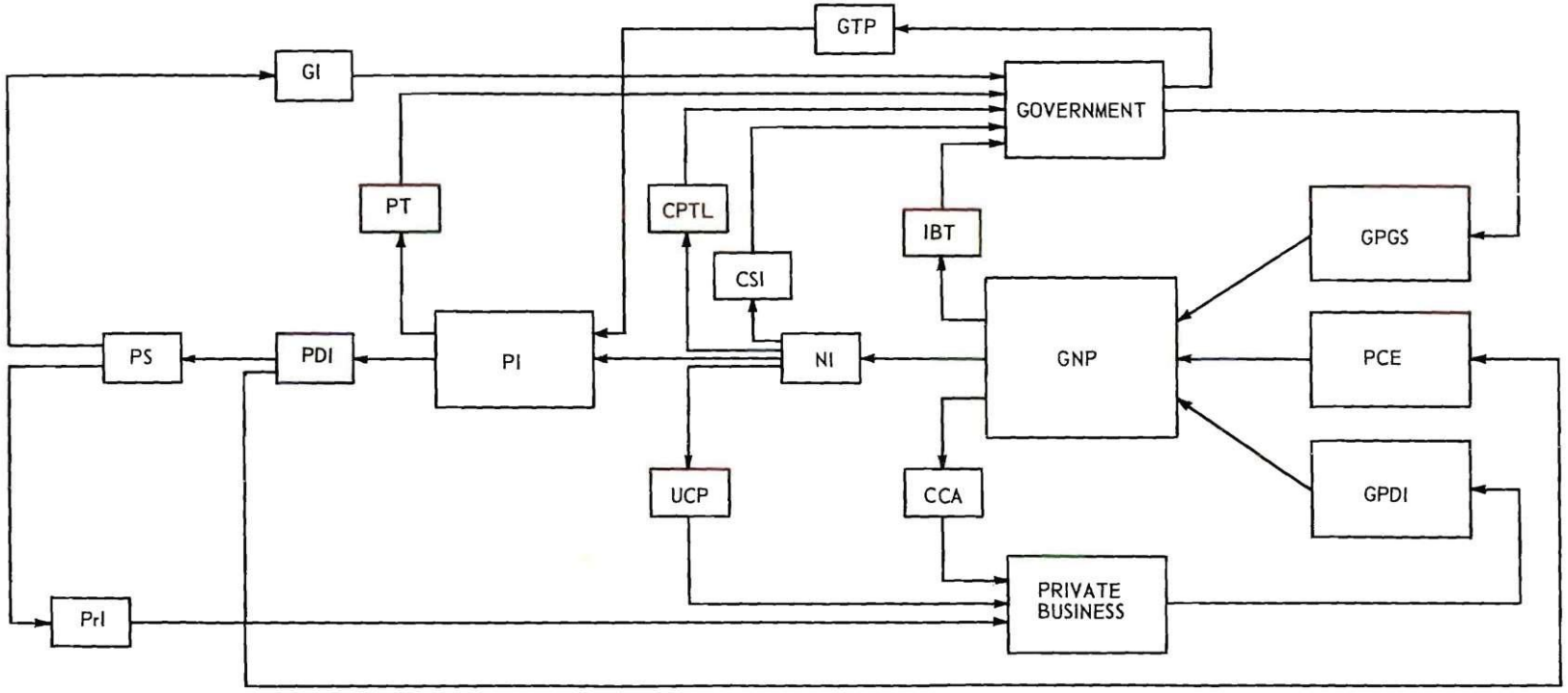

Figure 1. Flow of Spending and Income (General).

consideration. The constants in the equations were estimated from previous data obtained from a nineteen-year period.

(5). Hick's General Symbolic Model.[9] Hicks has three non-linear equations with three endogeneous variables and one exogeneous variable. He is undoubtedly only interested in establishing a model and not in the solution of the model. He later adds four more equations to the original three--continuing to state the nature of the function, but not giving the mathematical shape of the function.

(6). Maisel's Analogue Model of the Flow of Money in the United States.[10] This analogue represents the flow of spending as a hydraulic pumping system through which income flows and in which each of the three major sectors--consumers, business, and government--is depicted as a pumphouse. In the center of the three major sectors is another pumping station with an inlet and outlet to each of the major sectors. This station represents financial institutions in which money is saved and from which money is borrowed.

(7). The Littler Symbolic Model.[11] There are only two differential equations with four endogeneous variables. This model cannot obviously be solved, but it does present some interesting relationships

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[9]E. F. Beach, Economic Models, New York, John Wiley & Sons, Inc., 1957, pp. 59-60.

[10]Maisel, op. cit., pp. 124-125.

[11]Beach, op. cit., pp. 89-91.

which vary with time.

(8). Samuelson's Investment Symbolic Model.[12] This model, which consists of three differential equations with three unknowns, can be solved. However, the model appears to be somewhat trivial, inasmuch as its solution has no practical application.

Criticism of Present Economic Models

Many students of economics are coming to accept the fact that the economist who considers situations in merely qualitative terms has little to offer. Many economists, after having examined limited data, have established qualitative theories from their reasoning of how a particular economic society should function. Such theories, based on insufficient information, do not always produce valid results.

Although most of the economic models discussed above cannot be solved (or would be of little value if solved), nevertheless, they represent a distinct contrast with the classical approach of merely qualitative reasoning. An engineering approach or, more specifically, one through the methods of econometrics, may in years to come be advanced enough to actually solve within reasonable accuracy forecasting problems relating to various cause-and-effect economic relationships. Econometrics is defined as the unification of three points of view

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[12]Beach, op. cit., pp. 85-89.

represented by economic theory, mathematics and statistics into a quantitative solution of economic problems.[13]

Physical Analogues as a Means of Investigating Economic Systems

In the past few years in many fields of engineering, science, and business, computers and simulators have come into use in solving complex problems, especially non-linear relations. A simulator[14] has a part-by-part correspondence to the system under study. A simulator can be thought of as a special purpose analog computer. Physical analogues are usually either mechanical, electrical, electronic, or hydraulic.[15]

The analog computer model can be designed to predict the performance of an economic system in a manner similar to that used in engineering control systems. Such a computer model will be especially useful in analyzing complex dynamic behavior systems which have feed-back and feed-forward components. The analog computer circuit is built from functional blocks, which are direct analogues of components in the system to be simulated. If the characteristics of the

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[13]A. H. Hansen, Business Cycle and National Income, New York, W. W. Norton & Co., Inc., 1951, p. 417.

[14]Paul Truninger, "An Engineering Approach to the Dynamic Behavior or Microeconomic Systems," Unpublished Thesis, Georgia Institute of Technology, Atlanta, Georgia, 1958, pp. 6-55. (M. S. Thesis)

[15]G. A. Philbrick, A Palimpset on the Electronic Analog Art, Philbrick Researches, Inc., Boston, 1955, pp. 127-129.

economic system are known, no complex dynamic equations need be written. All that is necessary is the selection of the computer block similar to the block in the economic system.

In preparing the foregoing literature survey, the author was unable to obtain evidence that an electronic analog computer has been used or considered in the study of the flow of spending and income in the United States. In any case the application of electronic analog computers to the simulation of non-physical problems is undoubtedly in the early stage.

CHAPTER II

THE DEVELOPMENT OF A MODEL FOR SPENDING AND INCOME

The purpose of this chapter is to develop a model for spending and income in the United States. Figure 2, which is based on Figure 1, is designed to show various relationships in greater detail. As there are 36 components involved, it will be desirable to define their meaning before further discussion of the model. Table 1 gives the explanation of the symbols used in identities of the model which are listed in Table 2. The quantity known as the gross national product (GNP) is defined as the total value of goods and services produced in the United States during a particular year. Its dollar value is computed in terms of the current market prices. The goods and services included in the GNP are those which are actually bought for final use in legal markets. These expenditures are the sum of four major items: (1) personal consumption expenditures, (2) gross private domestic investment, (3) government purchases of goods and services, and (4) net foreign investment. "Net foreign investment" measures the net change in the international assets and liabilities of this country arising from current transactions with foreign countries. This item is insignificant in

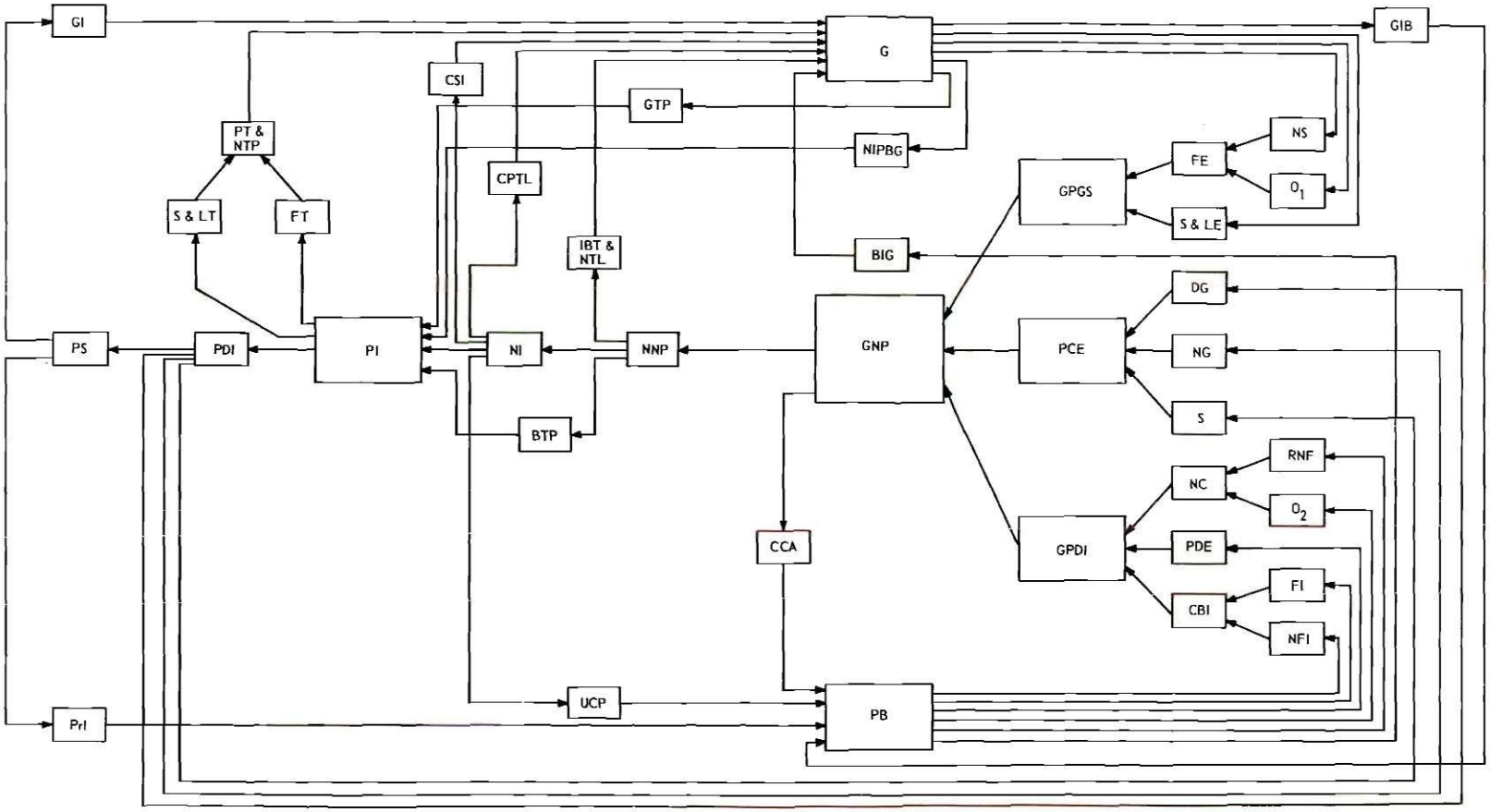


Figure 2. Flow of Spending and Income (Detailed).

Table 1. Explanation of Symbols Used in Identities

BIG	Business investment in government
BTP	Business transfer payments
CCA	Capital consumption allowances
CBI	Change in business inventories
O_2	Change in business inventories other than RNF
CSI	Contributions for social insurance
CPTL	Corporate profit tax liabilities
DG	Durable goods
FE	Federal expenditures
O_1	Federal expenditures other than NS
FT	Federal taxes
GI	Government institutions
GIB	Government investments in business
GPGS	Government purchases of goods and services
GR	Government receipts
GTP	Government transfer payments
GNP	Gross national product
GPDI	Gross private domestic investment
IBT & NTL	Indirect business taxes and non-tax liability
NI	National income
NS	National security

Table 1. (Continued)

NIPBG	Net interest paid by government
NNP	Net national product
NC	New construction
NG	Non-durable goods
PCE	Personal consumption expenditures
PDI	Personal disposable income
PI	Personal income
PS	Personal savings
PT & NTP	Personal tax and non-tax payments
PBE	Private business expenditures
PBR	Private business receipts
PrI	Private institutions
PDE	Producers' durable equipment
RNF	Residential non-farm construction
S	Services
S & LE	State and local expenditures
S & LT	State and local taxes
UCP	Undistributed corporate profits
FI	Farm income
NFI	Non-farm income

Table 2. Identities for Model

GNP = GPGS + PCE + GPDI

GPGS = FE + S & LE

FE = NS + O_1

PCE = DG + NG + S

GPDI = NC + PDE + CBI

NC = RNF + O_2

CBI = FI + NFI

NNP = GNP - CCA

NI = NNP - IBT & NTL - BTP

PI = NI - CPTL - UCP - CSI + GTP + NIPBG + BTP

PDI = PI - PT & NTP

PT&NTP = FT + S & LT

PS = DPI - DG - NG - S

PS = GI + PrI

GR = GI + PT & NTP + CSI + CPTL + IBT & NTL + BIG

GE = S & LE + O_1 + NS + NIPBG + GTP + GIB

PBR = CCA + UCP + PrI + GIB

PBE = CBI + PDE + NC + BIG

comparison with the GNP and introduces complicated relationships between several other larger items. In order to keep the model from becoming unduly complex, this item will be omitted and the GNP treated as the sum of personal consumption expenditures, gross private domestic investment, and government purchases of goods and services.

"Personal consumption expenditures" measures the sum of expenditures made by consumers (individuals, nonprofit institutions, etc.) for goods and services. These are durables (such as automobiles and television sets), nondurables (such as food and clothing), and services (such as house rent, motion pictures, medical expenses and legal advice).

"Gross private domestic investment" consists of new construction, producers' durable equipment, and changes in business inventories. "New construction" includes all the private construction of commercial structures, such as offices, plants, warehouses, pipelines, and gas and oil wells. It also includes construction on farms and new housing, regardless whether it is to be used for personal use or for rental. "Producers' durable equipment" includes the machines, tools, and other equipment used in commercial and industrial enterprises as well as tractors and other machinery purchases for use on farms. "Net change in business inventories" measures physical changes in business inventories which are valued at average prices prevailing during the year.

"Government purchases of goods and services" is those made by federal, state, and local governments. They include net purchases of new goods (such as school buildings and armaments), payments for services (principally compensation for government employees), gross investment by government enterprises, net government purchases from abroad, and international contributions. Items, such as transfer payments, which do not represent current productive activity are excluded.

"Net national product" is the GNP minus capital consumption allowances. "Capital consumption allowances" is composed of depreciation charges (an allowance for the cost of replacing plant and machinery), accidental damage to fixed capital (which measures the value of physical losses by fire, natural events, etc.), and capital outlays charged to current expense (which represent the purchases of new durable capital goods included in "gross private domestic investment" that are charged as current expense by business rather than entered on capital account).

"National income" is the net national product plus subsidies minus current surplus of government enterprises (this item is insignificant and is omitted from the model) minus indirect business taxes and non-tax liability minus business transfer payments. "Indirect business taxes" are taxes, such as manufacturers' sales or excise taxes, which are added to the cost of the product before it is sold. They increase

the market price (which is the basis for measuring the GNP) but do not represent a reward to a productive unit. "Non-tax liability," which is considered jointly with indirect business taxes, consists of payments for such specific services as are provided within the framework of general government activity. "Business transfer payments" consists of the monetary income receipts of individuals from business for which no services are rendered currently, of corporate gifts to nonprofit institutions, and of individuals' bad debts to business. "National income" can also be described as the total income earned by those contributing to current production. In this sense it is the sum of the following five major items: compensation of employees, proprietors' income, rental income of persons, net interest, and corporate profits.

"Personal income" is the national income minus undistributed corporate profits (i.e. those profits which are retained by business for expansion, investments, etc.) minus corporate profits tax liability (i.e. those profits which are transferred to the government) minus contributions for social insurance (i.e. that amount of money which business paid directly to the government for social security programs) minus corporate inventory adjustment and excess of wage accruals over disbursements (these two items are insignificant and will be omitted from the model) plus net interest paid by government plus government transfer payments plus business transfer payments. "Net interest paid by government" is the interest on stocks and bonds which were issued

by local, state, and federal government. "Government transfer payments" consists of monetary income receipts of individuals from government for which no services are rendered currently, and of government payments to nonprofit institutions. "Business transfer payments" is defined above. "Personal income" can also be described as the composite of income received currently by individuals, by unincorporated businesses, and by nonprofit institutions.

"Personal disposable income" is personal income minus personal tax and non-tax payments. These taxes account for the difference between wages or salaries before and after taxes. Included in these taxes are income taxes, property taxes, etc. These taxes are paid to federal, state, and local governments.

"Personal savings" is personal disposable income minus personal consumption expenditures. These expenditures were defined above. Individuals take these savings and place them in either government institutions or private institutions.

"Government receipts" is composed of the following items: savings in government institutions, personal tax and non-tax payments, contributions for social insurance, corporate profits tax liability, and indirect business tax and non-tax liability. "Government expenditures" is the purchases of goods and services of the federal, state, and local governments plus net interest paid by government plus government transfer payments. Federal expenditures are composed mainly of

"national security" expenditures.

It is obvious that the receipts and expenditures of consumers, business, and government will not always be equal when each is considered separately. However, when considered as a group, the total receipts must equal the total expenditures. If "private business" has an excess of earnings, it will invest in "government." Conversely, if government has an excess of receipts, it will invest in private business. Personal savings will, except in a serious recession, always be positive; these are invested in either government or private business, depending on attractiveness of the venture.

The above description defines the economic system which was analyzed in this study. Various contemplated changes and additions were not adopted. One possible change was the dividing of the block, government, into three blocks entitled "federal government," "state government," and "local government." Another was the inclusion of various debts, the debts of the above three government agencies, debts of private business, and debts of individuals and nonprofit institutions. There would also have been a "flow" into or out of the various debts blocks illustrating the increase or decrease of the debts. Factors which prohibited these changes were the following: data were not readily available, there were various complexities which would be introduced by the inter-relationships of the debt blocks with other existing blocks, and part of the data were listed according to fiscal years while

other data were listed by calendar years. Although this analog of spending and income does not correspond exactly with the actual system of which it is a model, it is hoped that it will be sufficiently accurate.

CHAPTER III

INSTRUMENTATION, EQUIPMENT, AND PROCEDURES

The model of spending and income as drawn in Figure 2 is at best only a diagramatic representation of the United States economy. Our economy is, however, very dynamic and should be represented by a dynamic type of model which will vary with time. The diagramatic model shown in Figure 2 is developed into an electronic analog shown in Figure 3. The electronic model in Figure 3 is the same model as in Figure 2, with the exception that most of the blocks are represented by analog computer components. Items in Figure 2 and Figure 3 are in the same relationship to each other for reference convenience.

Two series of experiments were conducted with the electronic model of the economic system. For brevity's sake, these two series of experiments are referred to as "Experiment 1" and "Experiment 2." Experiment 1 consisted of developing and refining the model which had previously been developed on paper. As a result of this first series of experiments, Experiment 2, which consisted of forecasting and the determining various effects of one block upon another, was performed. These experiments were conducted in the Analog Computer Laboratory of the Engineering Experiment Station, Georgia Institute of Technology, on the Berkeley Model 1032 Analog Computer.

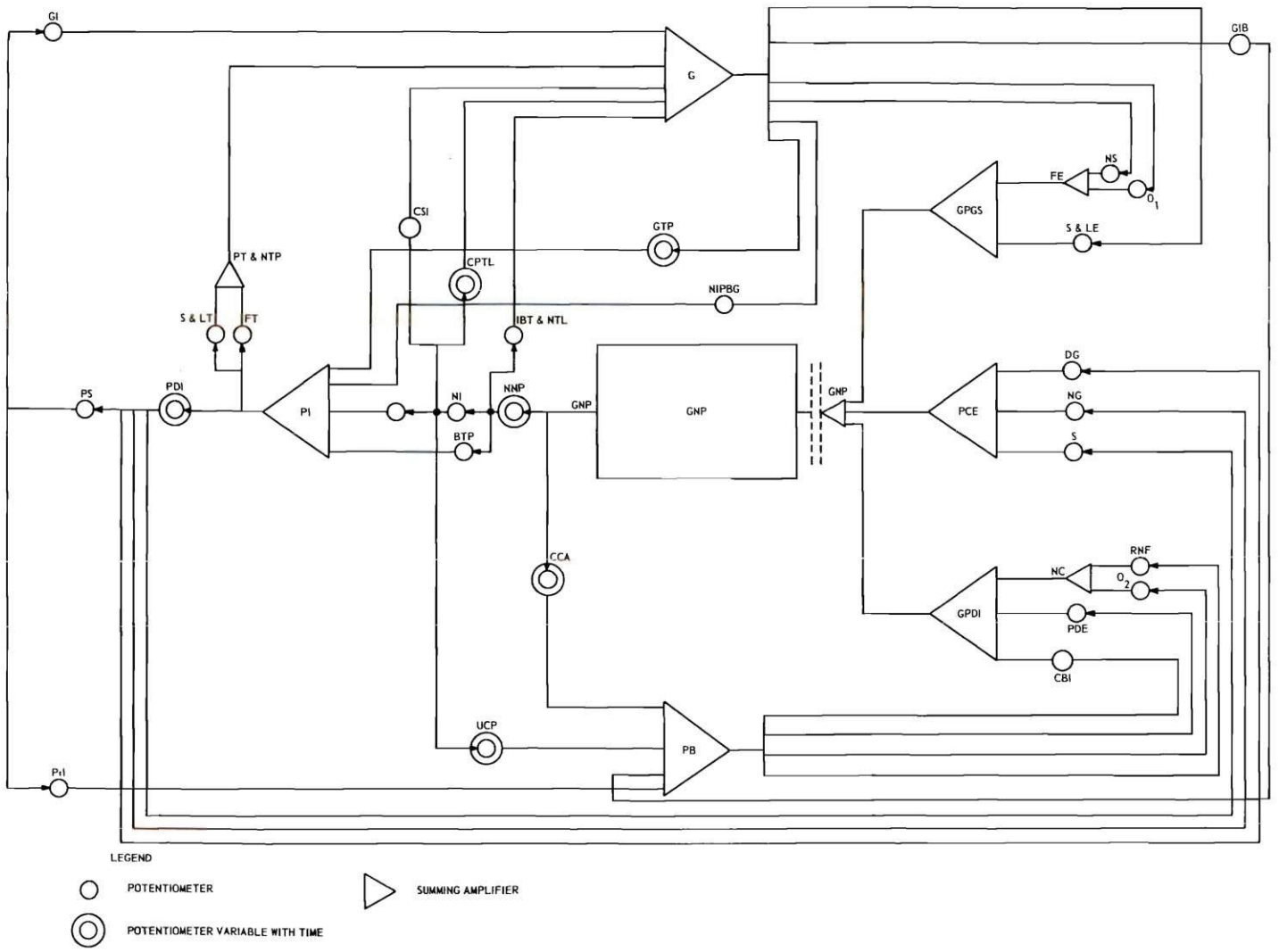


Figure 3. Electronic Analog of United States Flow of Spending and Income (General).

From Figure 3 the exact analog computer notation was derived and incorporated into Figure 4. Figure 4 is the actual analog program which was used in all experiments.

The electronic equipment which was used will be described along with the function which it performed in the analog circuitry.

Summing amplifiers. Twenty summing amplifiers were utilized. Their function was to add the various inputs at each stage into a composite item.

Integrating amplifiers. Three integraters were used. Their purpose was to integrate with respect to time and to actuate certain relays.

Potentiometers. Thirty-three potentiometers were used. These potentiometers distributed the income from a larger category down into smaller categories. A potentiometer was used when it was necessary to take a certain percentage of income from a summing amplifier or another potentiometer and distribute it according to a predetermined ratio. For the method used in determining the actual value of potentiometers, refer to Appendix I.

Servo resolver. One resolver was used. Its purpose was that of providing a changing ratio of the spending and income items to the GNP as required.

Multiplier. One multiplier was used. Its function was to multiply certain auxiliary components in the analog.

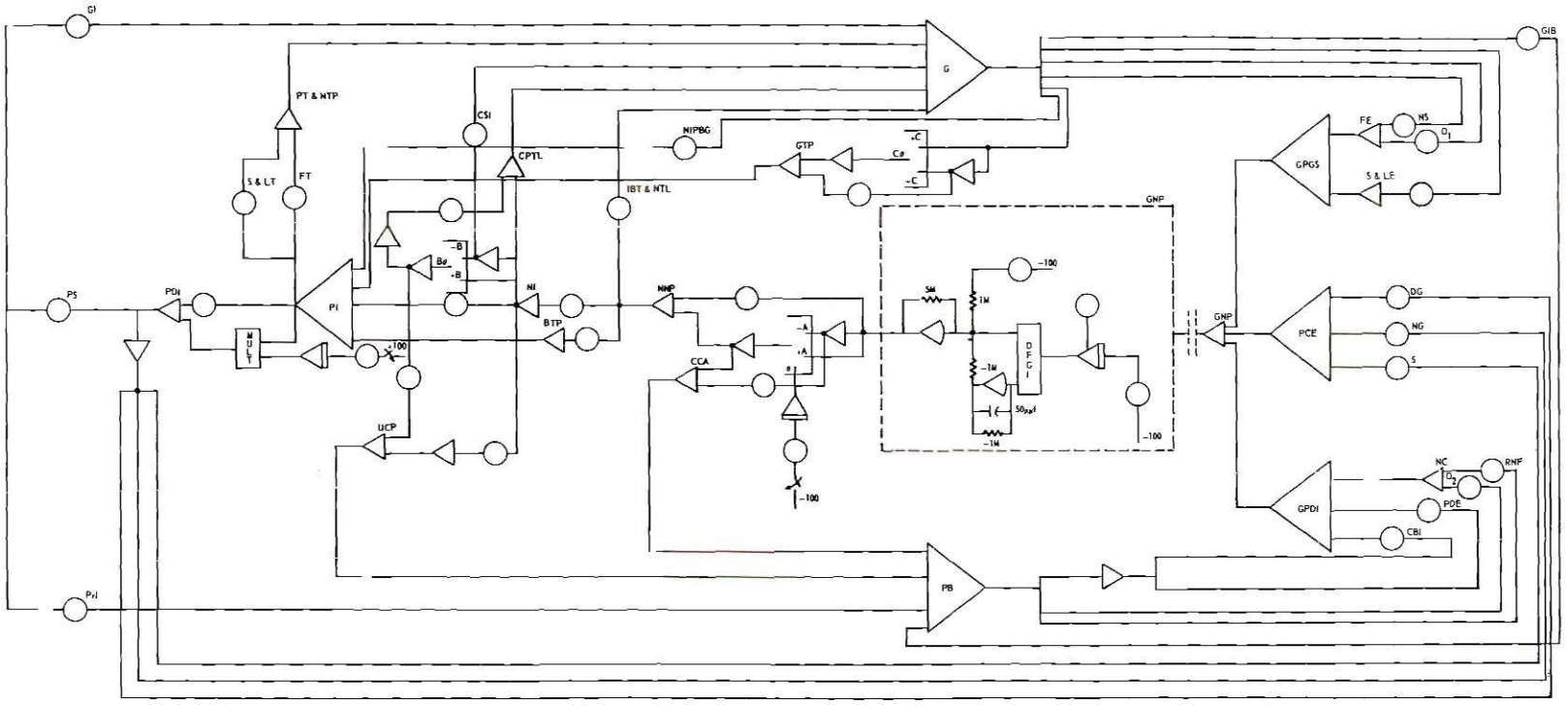


Figure 4. Electronic Analog of United States Flow of Spending and Income (Detailed).

Operational relay. One relay was used. It placed the resolver into action at a predetermined time.

X-Y recorder. All outputs recorded from the analog were drawn on the X-Y recorder with the X-axis being used as the time-axis.

Diode function generator. One function generator was used. Its values were changed three times. The function generator produced the forcing function for the entire analog by injecting into the analog a curve representing the growth of the GNP.

A schematic representation of the components referred to above is shown in Figure 5.

Experimental procedures were designed as follows:

1. Percentages of all "Incomes and Expenditures" to the GNP for all years from 1933 through 1949 (i.e. a total of 17 years) were obtained. These percentages are shown in Table 3 through Table 24.

2. These percentages were used in the setting of various components required in the analog for the forecasting of incomes and expenditures in future years.

3. The results forecasted for the years 1950 through 1954 were compared with the actual figures as obtained from the U. S. Department of Commerce.

4. As there was reason to believe that the figures were not representative of the actual results, modifications were attempted in order to arrive at a more accurate model.

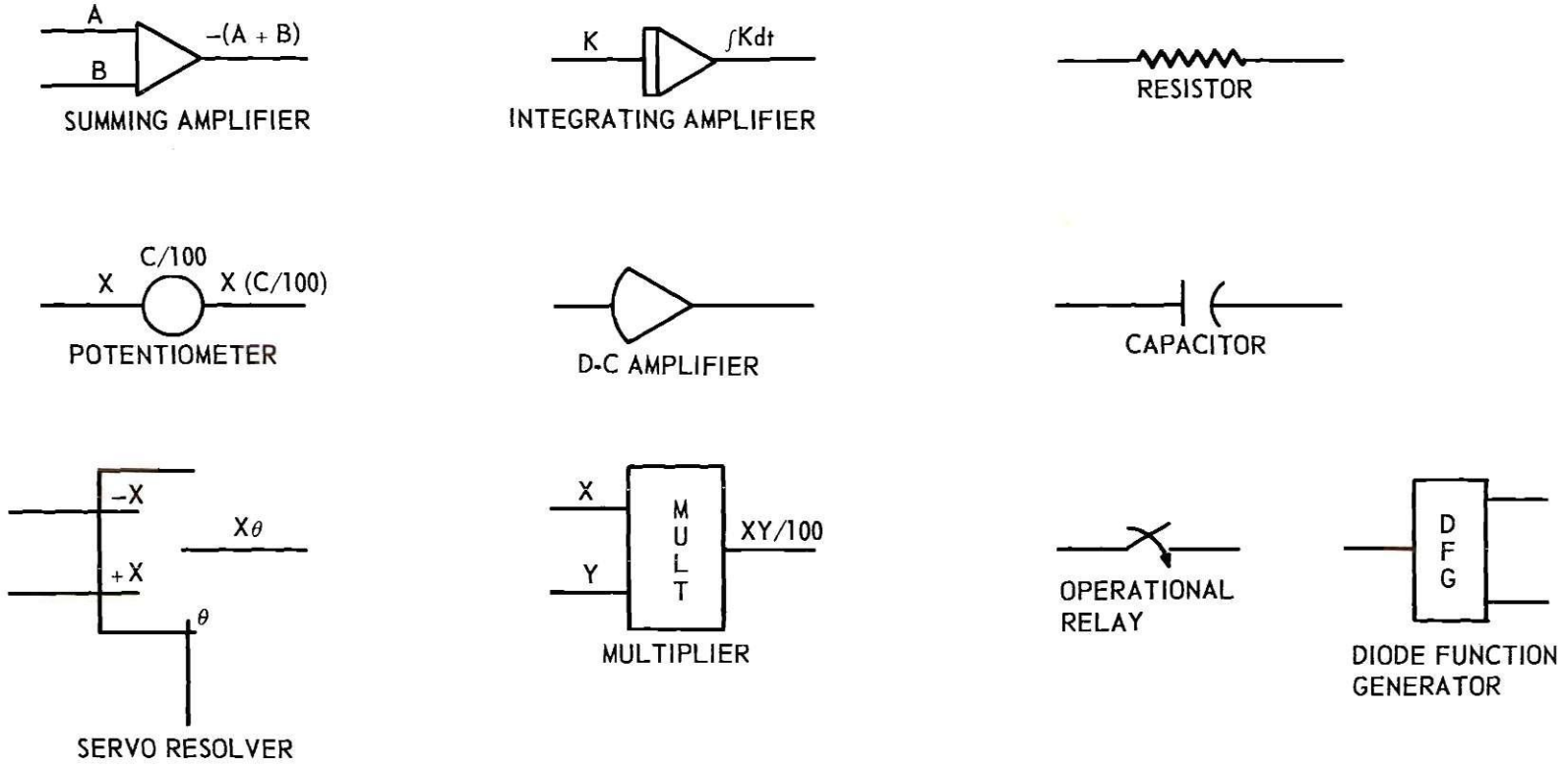


Figure 5. Explanation of Electronic Components of the Analog.

Table 3. Breakdown of Gross National Product for 1933

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	56.0	100.00	NG	22.3	39.82
CCA	7.9	14.11	S	20.7	36.96
NNP	47.3	84.46	NS	0.0	0.00
IBT & NTL	6.1	10.89	O_1	0.0	0.00
NI	40.2	71.79	S & LE	6.0	10.71
BTP	0.1	0.18	FE	2.0	3.57
CPTL	0.5	0.89	GPGS	8.0	14.28
CSI	0.2	0.36	PCE	46.4	82.86
PI	47.2	84.29	GPDI	1.4	2.50
UCP	-2.4	-4.29	NC	1.4	2.50
NIPBG	0.5	0.89	RNF	0.5	0.89
GTP	1.3	8.32	O_2	1.0	1.79
FT	0.5	0.89	PDE	1.6	2.86
S & LT	1.3	2.32	CBI	1.6	2.86
PT & NTP	1.5	2.68	F	0.2	3.57
PDI	45.7	81.61	NF	1.4	2.50
PS	-0.6	-1.07	BIG	1.1	1.97
DG	3.5	6.25	GIB	1.4	-2.50

Table 4. Breakdown of Gross National Product for 1934

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	65.0	100.00	NG	26.7	41.08
CCA	7.9	12.15	S	21.0	32.31
NNP	56.9	87.54	NS	0.0	0.00
IBT & NTL	6.8	10.46	O_1	0.0	0.00
NI	49.0	75.38	S & LE	6.8	10.46
BTP	0.2	0.31	FE	3.0	4.62
CPTL	0.7	1.08	GPGS	9.8	15.08
CSI	0.2	0.31	PCE	51.9	79.85
PI	53.6	82.46	GPDI	2.9	4.46
UCP	-1.6	-2.46	NC	1.7	2.62
NIPBG	0.7	1.08	RNF	0.6	0.92
GTP	1.4	2.15	O_2	1.1	1.69
FT	0.6	0.92	PDE	2.3	3.54
S & LT	1.5	2.31	CBI	1.1	1.69
PT & NTP	1.6	2.46	F	1.3	2.00
PDI	52.0	80.00	NF	0.2	0.31
PS	0.1	0.15	BIG	1.6	2.46
DG	4.2	6.46	GIB	-2.4	-3.70

Table 5. Breakdown of Gross National Product for 1935

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	72.5	100.00	NG	29.3	40.41
CCA	7.9	10.90	S	21.9	30.21
NNP	64.1	88.41	NS	0.0	0.00
IBT & NTL	7.1	9.80	O_1	0.0	0.00
NI	57.1	78.76	S & LE	7.1	9.79
BTP	0.2	0.28	FE	2.9	4.00
CPTL	1.0	1.38	GPGS	10.0	13.80
CSI	0.2	0.28	PCE	56.3	77.66
PI	60.2	83.03	GPDI	6.3	8.69
UCP	-0.7	-0.97	NC	2.3	3.17
NIPBG	0.7	0.97	RNF	1.0	1.38
GTP	1.6	2.21	O_2	1.3	1.79
FT	0.8	1.10	PDE	3.1	4.28
S & LT	1.7	2.34	CBI	0.9	1.24
PT & NTP	1.9	2.62	F	0.5	0.69
PDI	58.3	80.41	NF	0.4	0.55
PS	2.0	2.76	BIG	0.1	0.14
DG	5.1	7.03	GIB	-2.0	-2.76

Table 6. Breakdown of Gross National Product for 1936

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	82.7	100.00	NG	32.8	39.66
CCA	8.2	9.92	S	23.5	28.42
NNP	72.1	87.18	NS	0.0	0.00
IBT & NTL	7.4	8.95	O_1	0.0	0.00
NI	64.9	78.48	S & LE	7.0	8.52
BTP	0.2	0.24	FE	4.8	5.80
CPTL	1.4	1.69	GPGS	11.8	14.27
CSI	0.6	0.73	PCE	62.6	75.70
PI	68.5	82.83	GPDI	8.4	10.16
UCP	-0.2	-0.24	NC	3.3	3.99
NIPBG	0.7	0.85	RNF	1.6	1.93
GTP	2.6	3.14	O_2	1.7	2.06
FT	1.2	1.45	PDE	4.2	5.08
S & LT	1.7	2.06	CBI	1.0	1.21
PT & NTP	2.3	2.78	F	-1.1	-1.33
PDI	66.2	80.05	NF	2.1	2.54
PS	3.6	4.35	BIG	-1.8	-2.18
DG	6.3	7.62	GIB	-3.0	-3.63

Table 7. Breakdown of Gross National Product for 1937

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	90.8	100.00	NG	35.2	38.77
CCA	8.1	8.92	S	25.1	27.64
NNP	81.2	89.43	NS	0.0	0.00
IBT & NTL	7.5	8.26	O_1	0.0	0.00
NI	73.6	81.06	S & LE	7.2	7.93
BTP	0.3	0.33	FE	4.6	5.07
CPTL	1.5	1.65	GPGS	11.7	12.89
CSI	1.7	1.87	PCE	67.3	74.12
PI	73.9	81.39	GPDI	11.7	12.89
UCP	0.0	0.00	NC	4.4	4.84
NIPBG	0.8	0.88	RNF	1.9	2.09
GTP	1.7	1.87	O_2	2.5	2.75
FT	1.4	1.54	PDE	5.1	5.62
S & LT	1.7	1.87	CBI	2.2	2.42
PT & NTP	2.9	3.19	F	0.5	0.55
PDI	71.0	78.19	NF	1.7	1.87
PS	3.7	4.07	BIG	-4.0	-4.40
DG	6.9	75.99	GIB	0.6	0.66

Table 8. Breakdown of Gross National Product for 1938

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	85.2	100.00	NG	34.0	39.91
CCA	8.2	9.62	S	25.0	29.34
NNP	76.1	89.32	NS	0.0	0.00
IBT & NTL	7.3	8.57	O_1	0.0	0.00
NI	67.6	79.34	S & LE	7.5	8.80
BTP	0.3	0.35	FE	5.3	6.22
CPTL	1.0	1.17	GPGS	12.8	15.02
CSI	1.9	2.23	PCE	64.6	75.82
PI	68.6	80.52	GPDI	6.7	7.86
UCP	-0.9	-1.06	NC	4.0	4.69
NIPBG	0.9	1.06	RNF	2.0	2.35
GTP	2.5	2.93	O_2	1.9	2.23
FT	1.6	1.88	PDE	3.6	4.23
S & LT	1.7	2.00	CBI	-0.9	-1.06
PT & NTP	2.9	3.40	F	0.1	0.12
DPI	65.7	77.11	NF	-1.0	-1.17
PS	1.1	1.29	BIG	0.1	0.12
DG	5.7	6.69	GIB	-1.6	-1.88

Table 9. Breakdown of Gross National Product for 1939

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	91.1	100.00	NG	35.1	38.53
CCA	8.2	9.00	S	25.8	28.32
NNP	81.2	89.13	NS	1.3	1.42
IBT & NTL	8.6	9.44	O_1	3.9	4.28
NI	72.8	79.91	S & LE	8.2	9.00
BTP	0.4	0.44	FE	5.2	5.71
CPTL	1.4	1.54	GPGS	13.3	14.60
CSI	2.0	2.20	PCE	67.6	74.20
PI	72.9	80.02	GPDI	9.3	10.21
UCP	1.2	1.32	NC	4.8	5.27
NIPBG	1.0	1.10	RNF	2.7	2.96
GTP	2.5	2.74	O_2	2.0	2.20
FT	1.3	.43	PDE	4.2	4.61
S & LT	1.9	2.09	CBI	0.4	0.44
PT & NTP	2.4	2.63	F	0.1	0.11
DPI	70.4	77.28	NF	0.3	0.33
PS	2.9	3.18	BIG	-1.9	-2.09
DG	6.7	7.35	GIB	-2.1	-2.31

Table 10. Breakdown of Gross National Product for 1940

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	100.6	100.00	NG	37.2	36.98
CCA	8.4	8.40	S	26.9	26.74
NNP	91.3	90.76	NS	2.2	2.19
IBT & NTL	9.6	9.54	O_1	4.0	3.98
NI	81.6	81.11	S & LE	7.9	7.85
BTP	0.4	0.40	FE	6.2	6.16
CPTL	2.8	2.78	GPGS	14.1	14.02
CSI	2.1	2.09	PCE	71.9	71.47
PI	78.7	78.23	GPDI	13.2	13.12
UCP	2.4	2.39	NC	5.5	5.47
NIPBG	1.2	1.19	RNF	3.0	2.98
GTP	2.9	2.88	O_2	2.5	2.49
FT	1.4	1.39	PDE	5.5	5.47
S & LT	1.9	1.89	CBI	2.2	2.19
PT & NTP	2.6	2.58	F	0.3	0.30
DPI	76.1	75.65	NF	1.9	1.89
PS	4.2	4.17	BIG	-4.3	-4.26
DG	7.8	7.75	GIB	-0.7	-0.69

Table 11. Breakdown of Gross National Product for 1941

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	125.8	100.00	NG	43.2	34.34
CCA	9.0	7.15	S	29.0	23.05
NNP	116.8	92.85	NS	13.8	10.96
IBT & NTL	11.3	8.98	O_1	3.2	2.54
NI	104.7	83.22	S & LE	7.8	6.20
BTP	0.5	0.40	FE	16.9	13.43
CPTL	7.6	6.04	GPGS	24.8	19.71
CSI	2.8	2.23	PCE	81.9	65.10
PI	96.3	76.55	GPDI	18.1	14.39
UCP	4.9	3.90	NC	6.6	5.25
NIPBG	1.3	1.03	RNF	3.5	2.78
GTP	2.6	2.07	O_2	3.1	2.46
FT	2.0	1.59	PDE	6.9	5.48
S & LT	1.3	1.03	CBI	4.5	3.58
PT & NTP	3.3	2.62	F	0.5	0.40
DPI	93.0	73.93	NF	4.0	3.18
PS	11.1	8.82	BIG	-7.7	-6.10
DG	9.7	7.71	GIB	-3.8	-3.03

Table 12. Breakdown of Gross National Product for 1942

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	159.9	100.00	NG	51.3	32.24
CCA	10.2	6.41	S	31.5	19.80
NNP	149.0	93.65	NS	49.6	31.18
IBT & NTL	11.8	7.42	O_1	2.7	1.70
NI	137.7	86.55	S & LE	7.7	4.84
BTP	0.5	0.31	FE	52.0	32.68
CPTL	11.4	7.17	GPGS	59.7	37.52
CSI	3.5	2.20	PCE	89.7	56.38
PI	123.5	77.62	GPDI	9.9	6.22
UCP	5.2	3.27	NC	3.7	2.33
NIPBG	1.5	0.94	RNF	1.7	1.07
GTP	2.6	1.63	O_2	2.0	1.33
FT	4.7	2.95	PDE	4.3	2.70
S & LT	1.3	0.82	CBI	1.8	1.13
PT & NTP	6.0	3.77	F	1.1	0.69
DPI	117.5	73.85	NF	0.7	0.44
PS	27.8	17.47	BIG	4.5	2.82
DG	7.0	4.40	GIB	-31.4	-19.70

Table 13. Breakdown of Gross National Product for 1943

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	192.5	100.00	NG	59.3	30.81
CCA	10.9	5.66	S	34.7	18.03
NNP	181.6	94.34	NS	80.4	41.76
IBT & NTL	12.7	6.60	O_1	1.5	0.78
NI	170.3	88.47	S & LE	7.4	3.84
BTP	0.5	0.26	FE	81.2	42.18
CPTL	14.1	7.32	GPGS	88.6	46.03
CSI	4.5	2.34	PCE	100.5	52.21
PI	151.4	78.65	GPDI	5.6	2.91
UCP	6.0	3.12	NC	2.3	1.19
NIPBG	2.1	1.09	RNF	0.9	0.47
GTP	2.5	1.30	O_2	1.5	0.78
FT	16.5	8.57	PDE	4.0	2.08
S & LT	1.3	0.68	CBI	-0.8	-0.42
PT & NTP	17.8	9.25	F	-0.2	-0.10
DPI	133.5	69.35	NF	-0.6	-0.31
PS	33.0	17.14	BIG	12.9	6.65
DG	6.6	3.43	GIB	-44.2	-22.80

Table 14. Breakdown of Gross National Product for 1944

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	211.4	100.00	NG	65.4	30.94
CCA	120.0	5.67	S	37.7	17.83
NNP	199.4	94.32	NS	88.6	41.91
IBT & NTL	14.1	6.67	O_1	1.6	0.76
NI	182.6	86.38	S & LE	7.5	3.55
BTP	0.5	0.24	FE	89.0	42.10
CPTL	12.9	6.10	GPGS	96.5	45.63
CSI	5.2	2.46	PCE	109.8	51.94
PI	165.7	78.38	GPDI	7.1	3.36
UCP	5.7	2.70	NC	2.7	1.28
NIPBG	2.8	1.32	RNF	0.8	0.38
GTP	3.1	1.47	O_2	1.9	0.90
FT	17.5	8.28	PDE	5.4	2.55
S & LT	1.4	0.66	CBI	-1.0	-0.47
PT & NTP	18.9	8.94	F	-0.4	-0.19
DPI	146.8	69.44	NF	-0.6	-0.28
PS	36.9	17.46	BIG	12.2	5.80
DG	6.8	3.72	GIB	-51.9	-24.50

Table 15. Breakdown of Gross National Product for 1945

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	213.6	100.00	NG	73.2	34.27
CCA	12.5	5.85	S	40.4	18.91
NNP	201.0	94.10	NS	75.9	35.53
IBT & NTL	15.5	7.26	O_1	1.0	0.47
NI	181.2	84.83	S & LE	8.1	3.79
BTP	0.5	0.23	FE	74.8	35.01
CPTL	10.7	5.01	GPGS	82.9	38.81
CSI	6.1	7.86	PCE	121.7	56.98
PI	171.2	80.15	GPDI	10.4	4.87
UCP	3.6	1.69	NC	3.8	1.78
NIPBG	3.7	1.73	RNF	1.1	0.51
GTP	5.6	2.62	O_2	2.8	1.31
FT	19.4	9.08	PDE	7.7	3.60
S & LT	1.5	0.70	CBI	-1.1	-0.51
PT & NTP	20.9	9.78	F	-0.5	-0.23
DPI	150.4	70.41	NF	-0.6	-0.28
PS	28.7	13.44	BIG	6.6	3.10
DG	8.1	3.79	GIB	-39.7	-18.60

Table 16. Breakdown of Gross National Product for 1946

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	209.2	100.00	NG	84.5	40.39
CCA	11.7	5.59	S	46.2	22.08
NNP	197.6	94.46	NS	21.2	10.13
IBT & NTL	17.3	8.27	O_1	2.5	1.20
NI	179.6	85.85	S & LE	10.0	4.78
BTP	0.6	0.28	FE	20.9	9.99
CPTL	9.1	4.35	GPGS	30.9	14.77
CSI	6.0	2.87	PCE	146.6	70.08
PI	178.0	85.09	GPDI	27.1	12.95
UCP	7.7	3.68	NC	10.3	5.14
NIPBG	4.5	2.15	RNF	4.0	1.91
GTP	10.9	5.21	O_2	6.3	3.01
FT	17.2	8.22	PDE	10.7	5.11
S & LT	1.6	0.76	CBI	6.1	2.92
PT & NTP	18.8	8.99	F	-0.3	-0.14
DPI	159.2	76.10	NF	6.4	3.06
PS	12.6	6.02	BIG	-17.7	-8.05
DG	15.9	7.60	GIB	4.2	2.00

Table 17. Breakdown of Gross National Product for 1947

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	232.2	100.00	NG	93.1	40.09
CCA	14.1	6.03	S	51.3	22.09
NNP	218.1	93.93	NS	13.3	5.73
IBT & NTL	18.7	8.05	O_1	3.8	1.64
NI	197.2	84.93	S & LE	12.8	5.51
BTP	0.7	0.30	FE	15.8	6.80
CPTL	11.3	4.87	GPGS	28.6	12.32
CSI	5.7	2.45	PCE	165.0	71.06
PI	190.5	82.04	GPDI	29.7	12.79
UCP	11.7	5.04	NC	14.0	6.03
NIPBG	4.4	1.89	RNF	6.3	2.71
GTP	11.1	4.78	O_2	7.7	3.32
FT	19.7	8.48	PDE	16.7	7.19
S & LT	1.9	0.82	CBI	-1.0	-0.43
PT & NTP	21.5	9.26	F	-2.3	-0.99
DPI	169.0	72.78	NF	1.3	0.56
PS	4.0	1.72	BIG	-18.7	-8.08
DG	20.6	8.87	GIB	13.3	5.75

Table 18. Breakdown of Gross National Product for 1948

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	257.3	100.00	NG	98.7	38.36
CCA	16.5	6.41	S	56.7	22.04
NNP	240.8	93.59	NS	16.0	6.22
IBT & NTL	20.4	7.93	O_1	5.6	2.18
NI	221.6	86.13	S & LE	15.6	6.06
BTP	0.7	0.27	FE	21.0	8.16
CPTL	12.5	4.86	GPGS	36.6	14.22
CSI	5.2	2.02	PCE	177.0	68.79
PI	208.7	81.11	GPDI	41.2	16.01
UCP	13.0	5.05	NC	17.9	6.96
NIPBG	4.4	1.71	RNF	8.6	3.34
GTP	10.5	4.08	O_2	9.3	3.61
FT	19.0	7.38	PDE	19.1	7.42
S & LT	2.1	0.82	CBI	4.2	1.63
PT & NTP	21.1	8.26	F	1.2	0.47
DPI	187.6	72.91	NF	3.0	1.17
PS	10.0	3.89	BIG	-15.7	-6.10
DG	22.2	8.63	GIB	7.9	3.05

Table 19. Breakdown of Gross National Product for 1949

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	257.3	100.00	NG	96.9	37.66
CCA	18.4	7.15	S	60.1	23.36
NNP	238.9	92.85	NS	19.3	7.50
IBT & NTL	21.6	8.39	O_1	6.6	2.57
NI	216.2	84.03	S & LE	18.2	7.07
BTP	0.8	0.31	FE	25.4	9.87
CPTL	10.4	4.04	GPGS	43.6	16.95
CSI	5.7	2.22	PCE	180.6	70.19
PI	206.8	80.37	GPDI	32.5	12.63
UCP	8.3	3.23	NC	17.5	6.80
NIPBG	4.6	1.79	RNF	8.3	3.22
GTP	11.6	4.51	O_2	9.2	3.58
FT	16.2	6.30	PDE	17.8	6.92
S & LT	2.5	0.97	CBI	-2.7	-1.05
PT & NTP	18.7	7.27	F	-0.8	-0.31
DPI	188.2	3.14	NF	-1.9	-0.74
PS	7.6	2.95	BIG	-4.4	-1.70
DG	23.6	9.17	GIB	-3.2	-1.24

Table 20. Breakdown of Gross National Product for 1950

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	285.1	100.00	NG	100.4	35.00
CCA	20.5	7.19	S	65.0	22.80
NNP	264.6	92.81	NS	18.5	6.51
IBT & NTL	23.7	8.31	O_1	3.9	1.37
NI	240.0	84.18	S & LE	19.9	6.99
BTP	0.8	0.28	FE	22.1	7.75
CPTL	17.8	6.25	GPGS	42.0	14.73
CSI	6.9	2.42	PCE	194.0	68.10
PI	227.1	83.10	GPDI	51.2	17.96
UCP	12.9	4.53	NC	22.7	7.97
NIPBG	4.7	1.65	RNF	12.6	4.42
GTP	14.3	5.00	O_2	10.2	3.58
FT	18.2	6.40	PDE	21.1	7.40
S & LT	2.7	0.95	CBI	7.4	2.59
PT & NTP	20.9	7.35	F	1.0	0.35
DPI	206.1	72.50	NF	6.4	2.24
PS	12.1	4.25	BIG	-20.4	-7.18
DG	28.6	10.15	GIB	8.1	2.83

Table 21. Breakdown of Gross National Product for 1951

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	328.2	100.00	NG	111.1	33.81
CCA	23.5	7.17	S	70.1	21.30
NNP	304.8	92.80	NS	37.3	11.38
IBT & NTL	25.6	7.81	O_1	4.2	1.29
NI	277.0	84.50	S & LE	21.8	6.65
BTP	1.0	0.31	FE	41.0	12.51
CPTL	22.5	6.85	GPGS	62.8	19.10
CSI	8.2	2.49	PCE	208.3	63.70
PI	255.3	78.00	GPDI	56.9	17.32
UCP	9.6	2.92	NC	23.3	7.12
NIPBG	4.8	1.46	RNF	11.0	3.35
GTP	11.6	3.55	O_2	12.3	3.75
FT	26.3	7.97	PDE	23.2	7.06
S & LT	3.0	0.92	CBI	10.4	3.16
PT & NTP	29.3	8.95	F	1.4	0.43
DPI	226.1	69.00	NF	9.0	2.73
PS	17.7	5.40	BIG	-25.2	-7.69
DG	27.1	8.27	GIB	6.2	1.89

Table 22. Breakdown of Gross National Product for 1952

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	345.2	100.00	NG	116.0	33.60
CCA	25.5	7.40	S	75.7	21.85
NNP	319.7	92.60	NS	48.8	14.10
IBT & NTL	28.1	8.10	O_1	5.8	1.68
NI	289.5	83.70	S & LE	23.2	6.72
BTP	1.2	0.35	FE	54.3	15.72
CPTL	19.8	5.75	GPGS	77.5	22.40
CSI	8.6	2.49	PCE	218.3	63.21
PI	271.1	78.50	GPDI	49.6	14.36
UCP	7.1	2.06	NC	23.7	6.86
NIPBG	4.9	1.42	RNF	11.1	3.19
GTP	12.0	3.48	O_2	12.7	3.69
FT	31.2	9.05	PDE	23.1	6.71
S & LT	3.2	0.93	CBI	2.8	0.81
PT & NTP	34.4	9.90	F	0.7	0.20
DPI	236.7	68.50	NF	2.1	0.61
PS	18.4	5.31	BIG	-15.8	-4.59
DG	26.6	7.72	GIB	-3.3	-0.96

Table 23. Breakdown of Gross National Product for 1953

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	364.5	100.00	NG	118.9	32.81
CCA	27.8	7.65	S	81.8	22.43
NNP	336.7	92.35	NS	51.4	14.09
IBT & NTL	30.2	8.30	O_1	8.5	2.33
NI	303.6	83.50	S & LE	25.0	6.85
BTP	1.2	3.30	FE	59.5	16.34
CPTL	21.3	5.85	GPGS	84.5	23.21
CSI	8.7	2.39	PCE	230.6	63.22
PI	286.2	78.50	GPDI	51.4	14.08
UCP	7.7	2.12	NC	25.8	7.08
NIPBG	5.0	1.37	RNF	11.9	3.28
GTP	12.8	3.53	O_2	13.8	3.79
FT	32.4	8.88	PDE	24.4	6.71
S & LT	3.4	0.94	CBI	1.2	0.33
PT & NTP	35.8	9.81	F	-0.7	-0.19
DPI	250.4	68.80	NF	1.9	0.52
PS	19.8	5.47	BIG	-15.1	-4.15
DG	29.8	8.20	GIB	-6.0	-1.65

Table 24. Breakdown of Gross National Product for 1954

	Billions of Dollars	Per Cent of GNP		Billions of Dollars	Per Cent of GNP
GNP	360.5	100.00	NG	120.9	33.61
CCA	30.0	8.32	S	86.4	23.91
NNP	330.4	91.68	NS	43.2	11.93
IBT & NTL	30.3	8.42	O_1	6.3	1.75
NI	299.7	83.20	S & LE	27.8	7.71
BTP	1.2	3.32	FE	49.2	13.66
CPTL	17.1	4.75	GPGS	77.0	21.40
CSI	9.6	2.67	PCE	236.5	65.64
PI	287.6	79.50	GPDI	47.2	13.10
UCP	7.0	1.95	NC	27.8	7.73
NIPBG	5.2	1.44	RNF	13.5	3.77
GTP	15.0	4.17	O_2	14.3	3.97
FT	29.1	8.05	PDE	22.3	6.21
S & LT	3.7	1.01	CBI	-2.9	-0.81
PT & NTP	32.8	9.11	F	0.3	0.08
DPI	254.8	71.00	NF	-3.2	-0.89
PS	18.3	5.09	BIG	-10.2	-2.83
DG	29.3	8.15	GIB	-7.2	-1.99

5. Following the modifications, there was no reason to believe that the figures were not representative of the actual results. Consequently, a new set of figures was derived, utilizing the years 1933 through 1954 for the purpose of bringing up to date any slow changes that might be occurring both in GNP and in the spending and income items.

6. These result were then used for forecasting income and expenditures for the years 1954 through 1961. An attempt was made also to project the GNP until the year 2000. The results of these calculations are shown in Appendix II.

7. The analog readily lends itself to the study of cause-and-effect relationships between various blocks. As an illustration, the investment in producers' durable equipment was selected as a dependent variable and five blocks (described in detail in Chapter V) were varied.

CHAPTER IV

A DISCUSSION OF THE EMPIRICAL RELATIONSHIPS USED AND THE RESULTS OBTAINED IN THE ELECTRONIC ANALOG (EXPERIMENT 1)

Gross National Product.--The basic curve used to approximate the gross national product (GNP) is exponential, as it is well recognized that the rate of growth of the GNP is proportional to its size. Table 25 shows the data used in fitting the least squares curve for the GNP using a logarithmic transformation. This curve was plotted in Figure 6 in order that coordinates could be obtained for setting the function generator of the analog computer. Table 26 compares the estimated least squares curve with the actual. The former curve was not considered to be accurate enough when forecasting the years 1950 to 1954 and generally comparing the theoretical results with the actual results. The main reason for the above conclusion was the fact that the effect of the cyclical variation was not considered.

The simple exponential curve mentioned above was therefore discarded as a means of forecasting the GNP. It was then decided to analyze the data from 1913 - 1949 (i.e. an extension into the past 20 years) with the objective of obtaining a better forecasting curve.

Table 25. Calculation of Least Squares Exponential Curve of GNP (1933 - 1949) Using a Logarithmic Transformation

Year	Log GNP*	t	t^2	t Log GNP
1933	1.74819	-8	64	-13.9856
1934	1.81291	-7	49	-12.6904
1935	1.86034	-6	36	-11.1620
1936	1.91751	-5	25	-9.5875
1937	1.95809	-4	16	-8.1236
1938	1.93044	-3	9	-5.7913
1939	1.95952	-2	4	-3.9188
1940	2.00260	-1	1	-2.0026
1941	2.09968	0	0	0
1942	2.20167	1	1	2.2017
1943	2.28443	2	4	4.5697
1944	2.32510	3	9	6.9753
1945	2.32960	4	16	9.3184
1946	2.32056	5	25	11.6028
1947	2.36586	6	36	14.1952
1948	2.41044	7	49	16.8731
1949	2.41044	8	64	19.2835
Totals	35.93738	0	408	17.7579

*Refer to Table 3 through Table 24 for dollar values of GNP.

Log GNP = 1.76596 + .04352 t, t = 0 in 1933

GNP = 58.34 $(1.1055)^t$

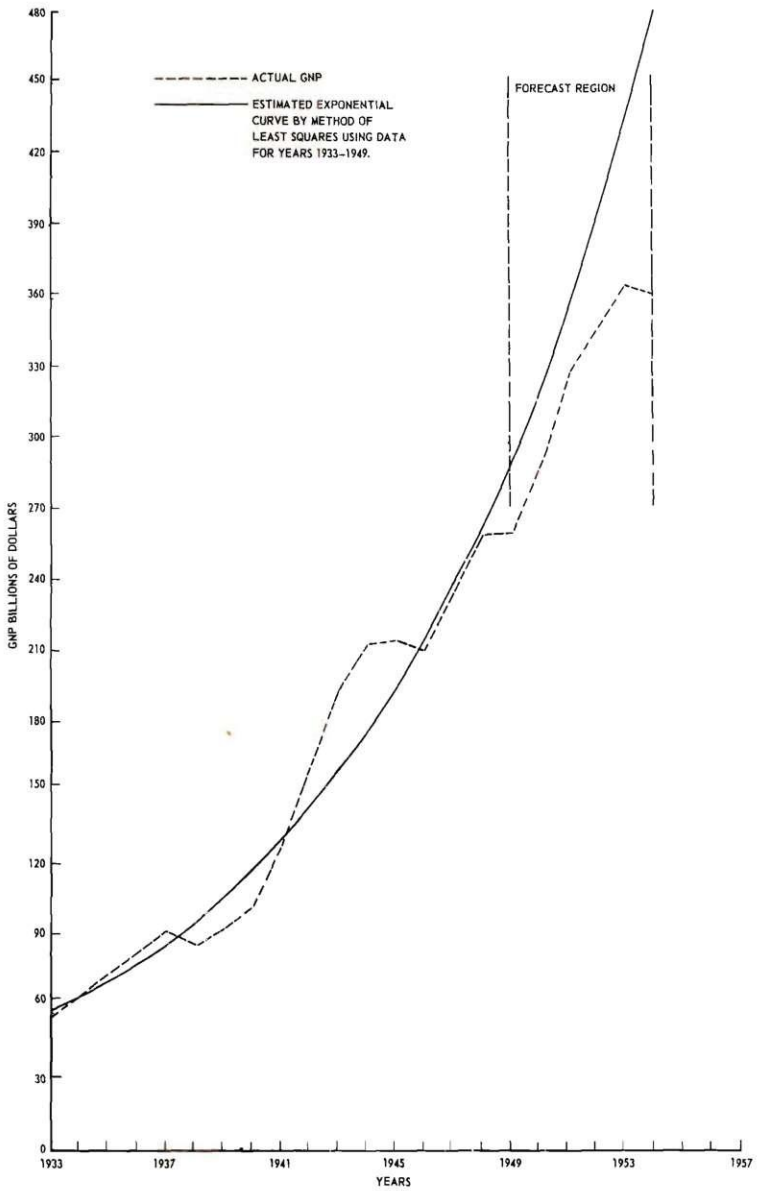


Figure 6. Fitting Exponential Curve to GNP (1933-1949).

Table 26. Comparison of Estimated Exponential Least Squares Data with Actual Data of GNP (1933 - 1949) Using a Logarithmic Transformation

Year	Actual Log GNP	Log Difference	Estimated Log GNP
1933	1.74819	0.01777	1.76596
1934	1.81291	-0.00343	1.80948
1935	1.86034	-0.00734	1.85300
1936	1.91751	-0.02099	1.89652
1937	1.95809	-0.01805	1.94004
1938	1.93044	0.05312	1.98356
1939	1.95952	0.06756	2.02708
1940	2.00260	0.06800	2.07060
1941	2.09968	0.01444	2.11412
1942	2.20167	-0.04403	2.15764
1943	2.28443	-0.08327	2.20116
1944	2.32510	-0.08042	2.24468
1945	2.32960	-0.04140	2.28820
1946	2.32056	0.01116	2.33172
1947	2.36586	0.00938	2.37524
1948	2.41044	0.00832	2.41876
1949	2.41044	0.051044	2.46228
1950*	2.45483	0.05097	2.50580
1951*	2.51592	0.03341	2.54932
1952*	2.53780	0.05504	2.59284
1953*	2.56108	0.07528	2.63636
1954*	2.55627	0.12361	2.67988

*These years were forecast using the 1933 - 1949 data.

Table 27 shows the data used in the least squares approximation for the period 1913 - 1949. Table 28 shows the difference between the actual GNP and estimated GNP for the period 1913 - 1949. It is further observed that this difference is cyclical in nature: the actual GNP was greater than the estimated GNP for 14 consecutive years (denoted by a minus difference) and the actual GNP was less than the estimated GNP for 13 consecutive years (denoted by a plus difference). An approximation to this cyclical fluctuation component of the GNP will be 0.15 $\sin \frac{\pi t}{13}$ with "t" in years and t = 0 at 1916. The value of 0.15 was obtained by averaging the differences. The curve as plotted from the data shown in Table 28 appears in Figure 7. This curve is considered to be adequate for forecasting since it is much closer to the actual results than the pure exponential curve. Table 29 shows the comparison of results obtained by the two curves with the actual data.

Spending and Income Items. --The spending and income items which were considered in the analog are listed below. The quantitative relationships determined for each item were as a percentage relative to the GNP. The actual value of the items as a percentage of the GNP, the trend, and the forecasted percentages are shown in Figure 8 through Figure 42 for all items considered in the model. These relationships were determined by various methods employing both quantitative and qualitative reasoning. Each item is discussed below in the same order as the corresponding figures appear.

Table 27. Calculation of Least Squares Exponential Curve of GNP (1913 - 1949) Using a Logarithmic Transformation

Year	Log GNP *	t	t^2	t Log GNP
1913	1.6232	-18	324	-29.2176
1914	1.6128	-17	289	-27.4176
1915	1.6415	-16	256	-26.2640
1916	1.7067	-15	225	-25.6005
1917	1.7803	-14	196	-24.9242
1918	1.8519	-13	169	-24.0747
1919	1.8893	-12	144	-22.6716
1920	1.9400	-11	121	-21.3400
1921	1.8727	-10	100	-18.7270
1922	1.8893	- 9	81	-17.0037
1923	1.9415	- 8	64	-15.5320
1924	1.9576	- 7	49	-13.7032
1925	1.9841	- 6	36	-11.9046
1926	2.0033	- 5	25	-10.0165
1927	2.0120	- 4	16	- 8.0480
1928	2.0198	- 3	9	- 6.0594
1929	2.0187	- 2	4	- 4.0374
1930	1.9595	- 1	1	- 1.9595
1931	1.8825	0	0	0
1932	1.7672	1	1	1.7672
1933	1.7482	2	4	3.4964
1934	1.8129	3	9	5.4387
1935	1.8603	4	16	7.4412
1936	1.9175	5	25	9.5875
1937	1.9581	6	36	11.7486
1938	1.9304	7	49	13.5128
1939	1.9595	8	64	15.6760
1940	2.0026	9	81	18.0234
1941	2.0997	10	100	20.9970
1942	2.2017	11	121	24.2187
1943	2.2844	12	144	27.4128
1944	2.3251	13	169	30.2263
1945	2.3296	14	196	32.6144

Table 27. (Continued)

Year	Log GNP *	t	t^2	t Log GNP
1946	2.3206	15	225	34.8090
1947	2.3659	16	256	37.8544
1948	2.4104	17	289	40.9768
1949	2.4104	18	324	43.3872
Totals	73.3004	0	4218	87.6906

*Refer to Table 3 through Table 24 for dollar values of GNP.

Log GNP = 1.98109 + .02078 t, t = 0 in 1931

GNP = $95.73 (1.0490)^t$

Table 28. Comparison of Estimated Exponential Least Squares Data, Actual Data, and Estimated Exponential Plus Cyclical Component (1913 - 1949) Using a Logarithmic Transformation

Year	Actual Log GNP	Log Difference	Estimated Log GNP	Component Sine	Estimated Log GNP Plus Sine Component
1913	1.6232	-0.0163	1.6069	(Values omitted were	
1914	1.6128	0.0149	1.6277	of little interest)	
1915	1.6415	0.0070	1.6485		
1916	1.7067	-0.0375	1.6692	0	1.6692
1917	1.7803	-0.1097	1.6900	0.0358	1.7258
1918	1.8519	-0.1411	1.7108	0.0697	1.7805
1919	1.8893	-0.1577	1.7316	0.0994	1.8310
1920	1.9400	-0.1876	1.7524	0.1235	1.8759
1921	1.8727	-0.0995	1.7732	0.1402	1.9134
1922	1.8893	-0.0953	1.7940	0.1489	1.9429
1923	1.9415	-0.1267	1.8148	0.1489	1.9637
1924	1.9576	-0.1220	1.8356	0.1402	1.9758
1925	1.9841	-0.1271	1.8564	0.1235	1.9799
1926	2.0033	-0.1262	1.8771	0.0994	1.9765
1927	2.0120	-0.1011	1.8979	0.0697	1.9676
1928	2.0198	-0.1011	1.9187	0.0358	1.9545
1929	2.0187	-0.0792	1.9395	0	1.9395
1930	1.9595	0.0008	1.9603	0.0358	1.9245
1931	1.8825	0.0986	1.9811	0.0697	1.9114
1932	1.7672	0.2347	2.0019	0.0994	1.9025
1933	1.7482	0.2745	2.0227	0.1235	1.8992
1934	1.8129	0.2306	2.0435	0.1402	1.9033
1935	1.8603	0.2040	2.0643	0.1489	1.9154
1936	1.9175	0.1675	2.0850	0.1489	1.9361
1937	1.9581	0.1477	2.1058	0.1402	1.9652
1938	1.9304	0.1962	2.1266	0.1235	2.0031
1939	1.9595	0.1879	2.1474	0.0994	2.0480
1940	2.0026	0.1656	2.1682	0.0697	2.0985
1941	2.0997	0.0892	2.1889	0.6358	2.1531
1942	2.2017	0.0081	2.2097	0	2.2098
1943	2.2844	-0.0538	2.2306	0.0358	2.2664

Table 28. (Continued)

Year	Actual Log GNP	Log Difference	Estimated Log GNP	Component Sine	Estimated Log GNP Plus Sine Component
1944	2.3251	-0.0737	2.2514	0.0697	2.3211
1945	2.3296	-0.0574	2.2722	0.0994	2.3716
1946	2.3206	-0.0277	2.2929	0.1235	2.4164
1947	2.3659	-0.0522	2.3137	0.1402	2.4539
1948	2.4104	-0.0759	2.3345	0.1489	2.4834
1949	2.4104	-0.0551	2.3553	0.1489	2.5042

$$\text{Log GNP} = 1.98109 + .02078t + 0.15 \sin\left(\frac{\pi}{13}\right)t, \quad t = 0 \text{ in } 1931$$

$$\text{GNP} = 95.73\,(1.0490)^{t}\,(1.4125)^{\sin\left(\frac{\pi}{13}\right)t}$$

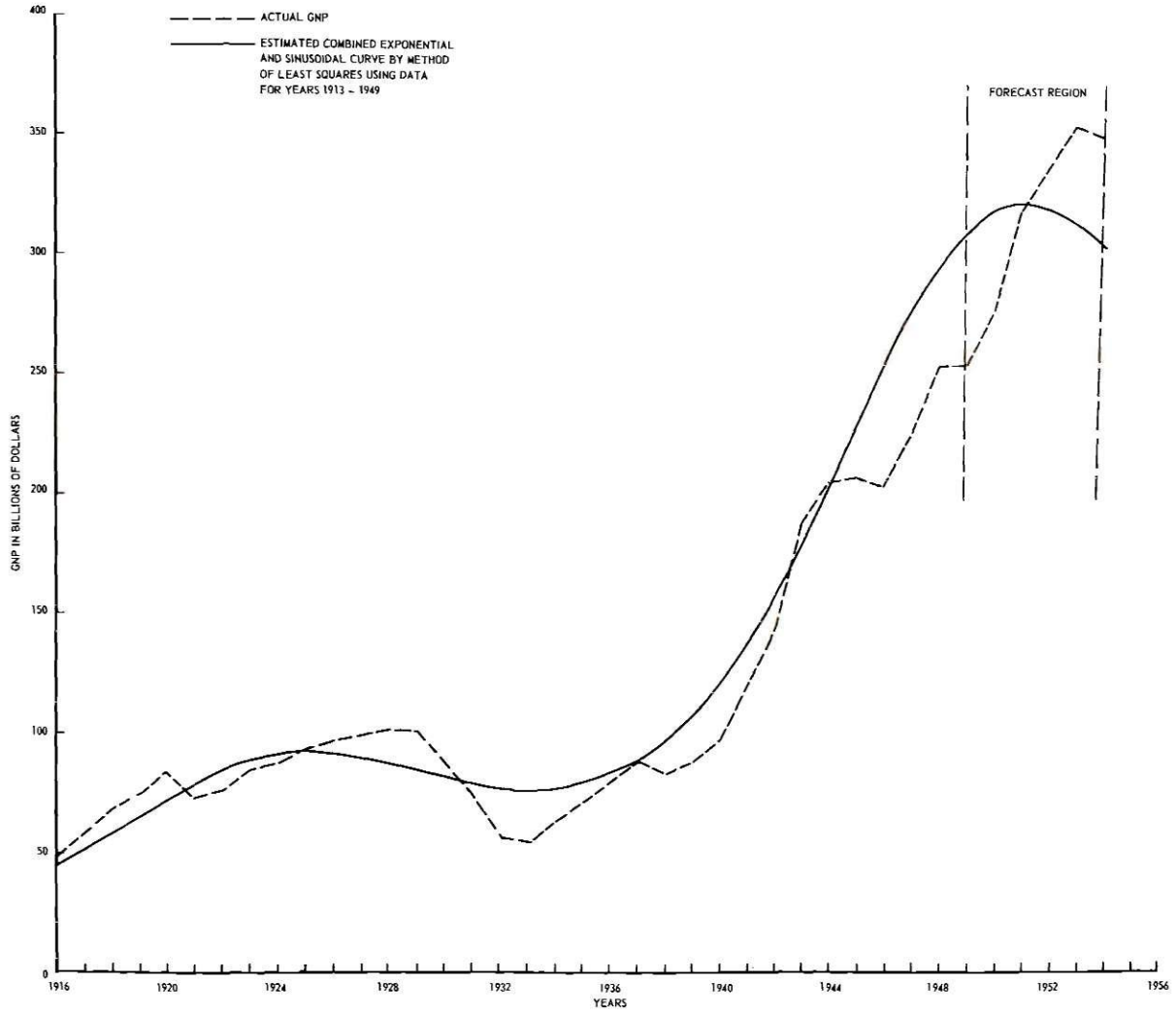


Figure 7. Fitting a Combined Exponential and Sinusoidal Curve to GNP (1916-1949).

Table 29. Comparison of the Exponential Data and the Combined Exponential with a Cyclical Component to the Actual GNP (1916 - 1949)

Year	Estimated Exponential GNP*	Actual GNP*	Estimated Exponential Plus Cyclical Component*
1916	46.7	50.9	50.6
1917	48.9	60.3	57.4
1918	51.4	71.1	65.0
1919	53.9	77.5	72.8
1920	56.5	87.1	80.5
1921	59.3	74.6	87.5
1922	62.2	77.5	93.4
1923	65.3	87.4	97.7
1924	68.5	90.7	100.0
1925	71.8	96.4	100.1
1926	75.3	100.8	99.3
1927	79.1	102.9	99.3
1928	83.0	104.7	94.3
1929	87.0	104.4	90.9
1930	91.3	91.1	87.5
1931	95.8	76.3	84.7
1932	100.4	58.5	82.7
1933	105.4	56.0	81.9
1934	110.5	65.0	82.4
1935	116.0	77.5	84.5
1936	121.6	82.7	88.4
1937	127.6	90.8	94.3
1938	133.9	85.2	102.6
1939	140.4	91.1	113.4
1940	147.3	100.6	127.1
1941	154.5	125.8	143.7
1942	162.1	159.1	163.2
1943	170.1	192.5	185.5
1944	178.4	211.4	209.8
1945	187.2	213.6	235.0
1946	196.3	209.2	259.8
1947	205.9	232.2	282.4
1948	216.0	257.3	301.5
1949	226.6	257.3	315.4

*All values are in billions of dollars.

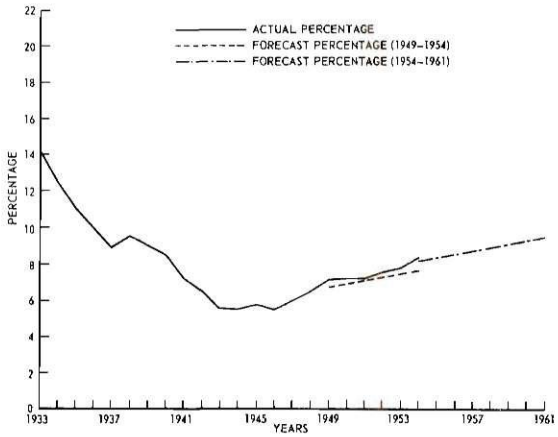


Figure 8. Percentage of Capital Consumption Allowances to GNP.

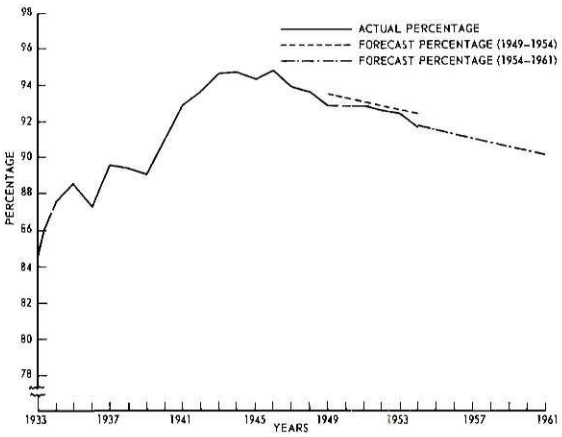


Figure 9. Percentages of Net National Product to GNP.

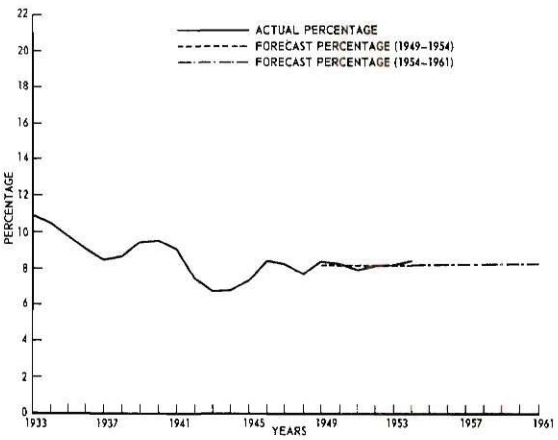


Figure 10. Percentage of Indirect Tax and Non-Tax Liability to GNP.

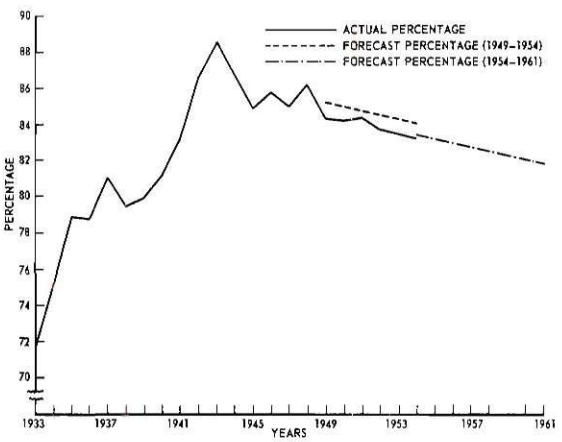


Figure 11. Percentage of National Income to GNP.

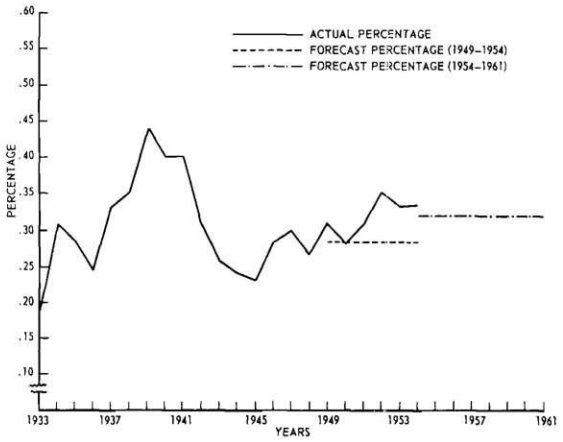


Figure 12. Percentage of Business Transfer Payments to GNP.

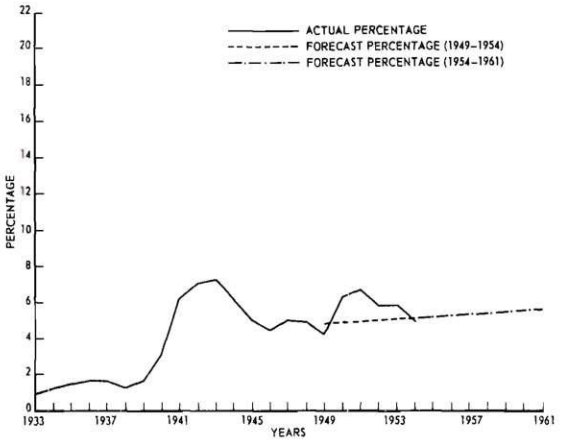


Figure 13. Percentage of Corporate Profits Tax Liability to GNP.

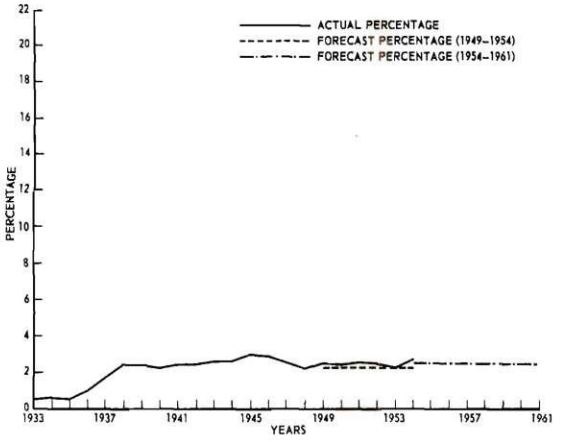


Figure 14. Percentage of Contributions for Social Insurance to GNP.

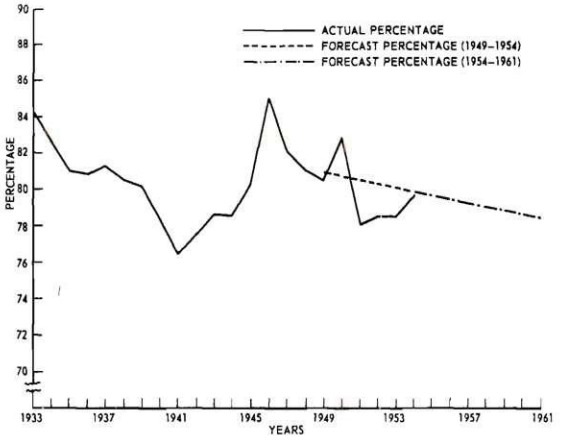


Figure 15. Percentage of Personal Income to GNP.

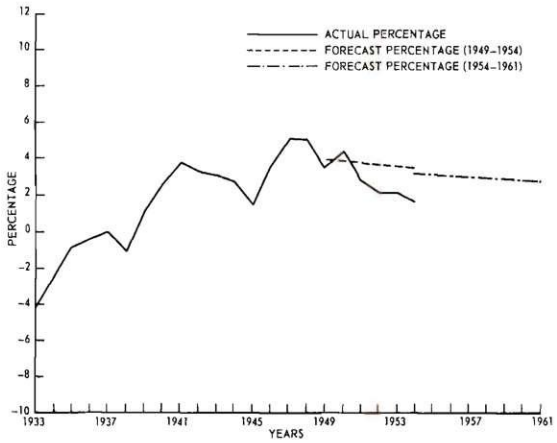


Figure 16. Percentage of Undistributed Corporate Profits to GNP.

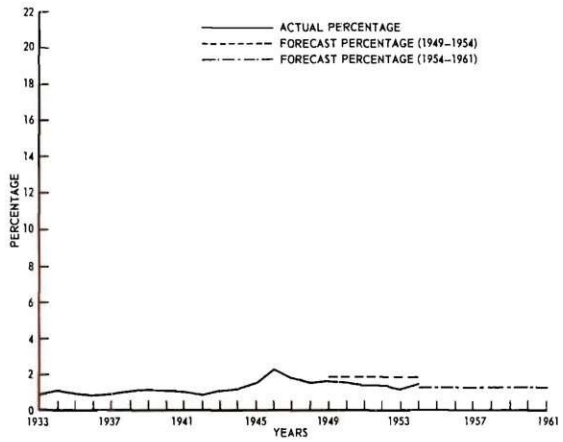


Figure 17. Percentage of Net Interest Paid by Government to GNP.

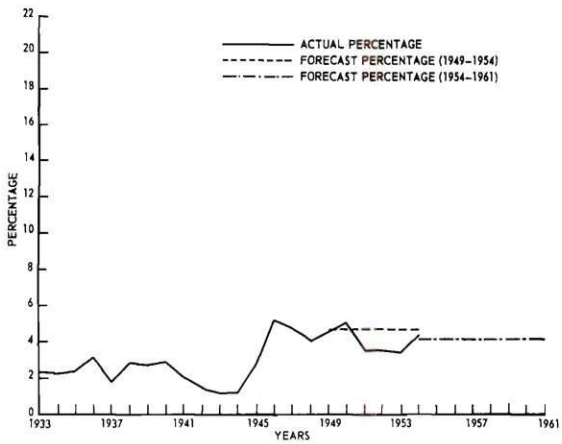


Figure 18. Percentage of Government Transfer Payments to GNP.

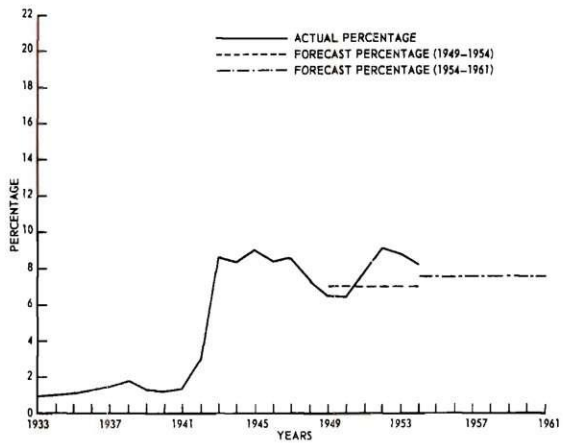


Figure 19. Percentage of Federal Taxes to GNP.

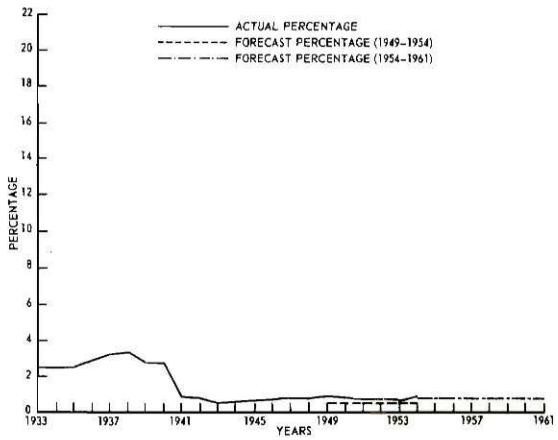


Figure 20. Percentage of State and Local Taxes to GNP.

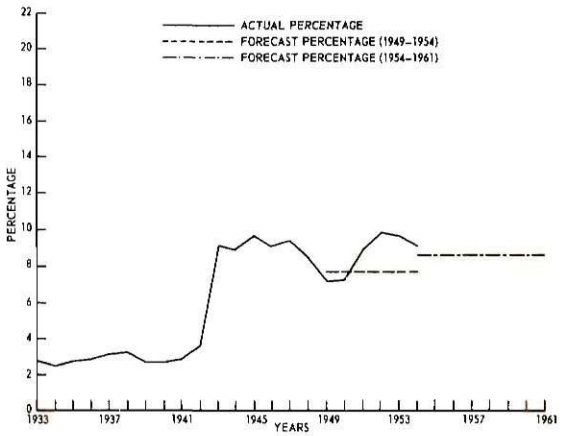


Figure 21. Percentage of Personal Tax and Non-Tax Payments to GNP.

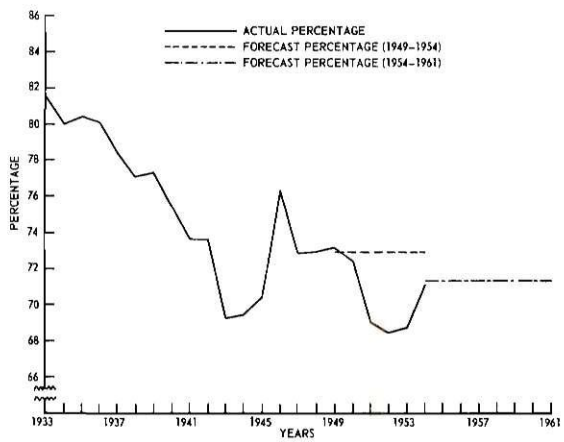


Figure 22. Percentage of Disposable Personal Income to GNP.

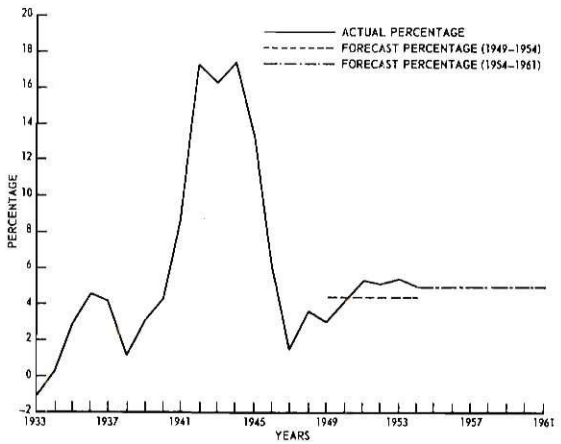


Figure 23. Percentage of Personal Savings to GNP.

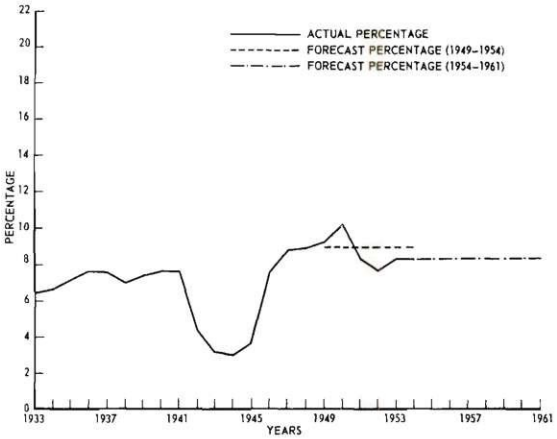


Figure 24. Percentage of Durable Goods to GNP.

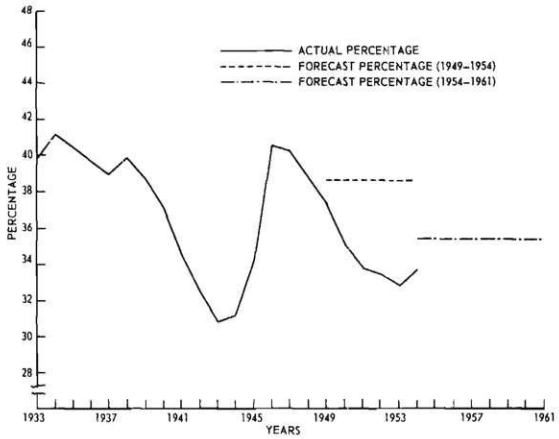


Figure 25. Percentage of Non-Durable Goods to GNP.

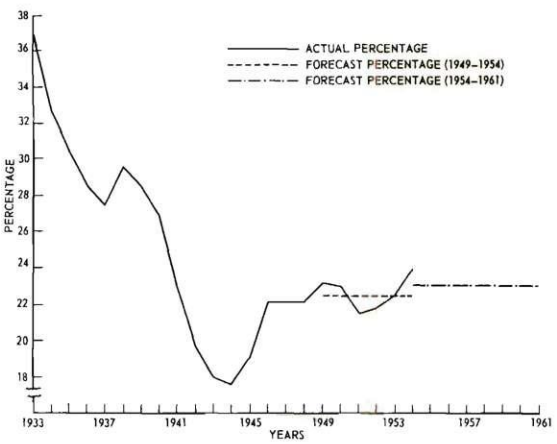


Figure 26. Percentage of Services to GNP.

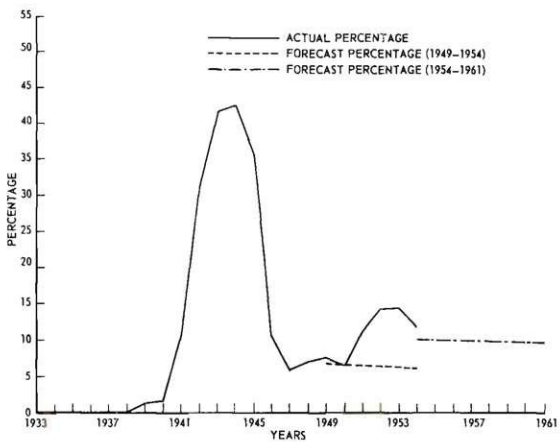


Figure 27. Percentage of National Security to GNP.

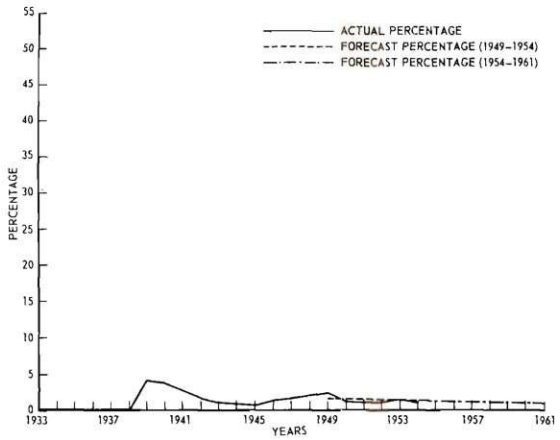


Figure 28. Percentage of Other Federal Expenditures to GNP.

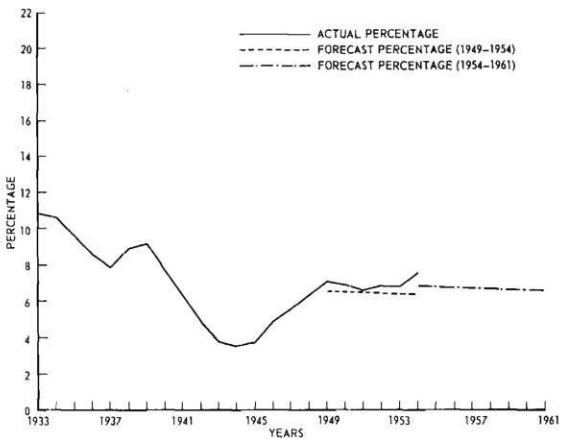


Figure 29. Percentage of State and Local Expenditures to GNP.

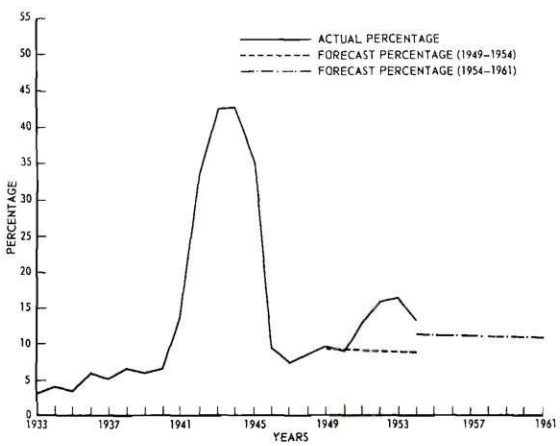


Figure 30. Percentage of Federal Expenditures to GNP.

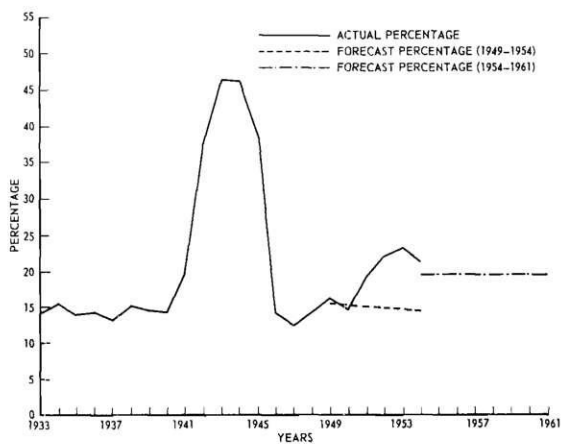


Figure 31. Percentage of Government Purchases of Goods and Services to GNP.

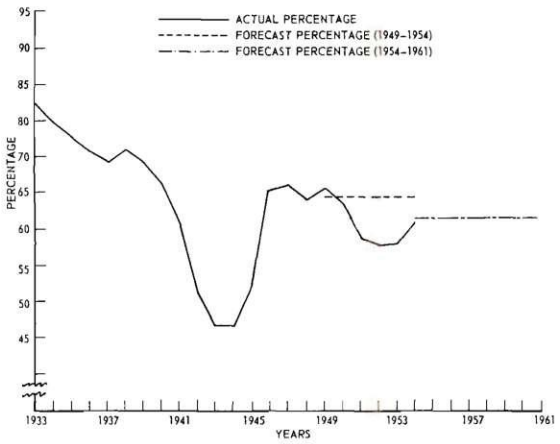


Figure 32. Percentage of Personal Consumption Expenditures to GNP.

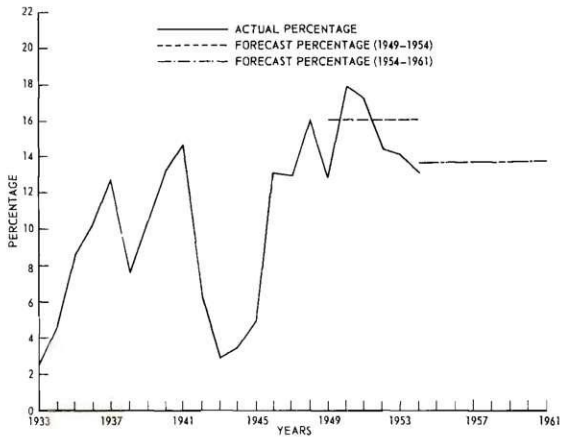


Figure 33. Percentage of Gross Private Domestic Investment to GNP.

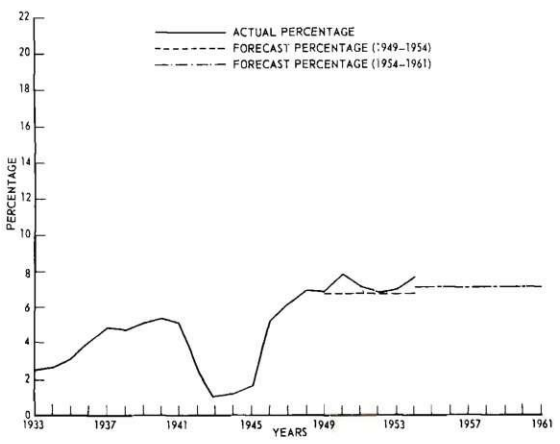


Figure 34. Percentage of New Construction to GNP.

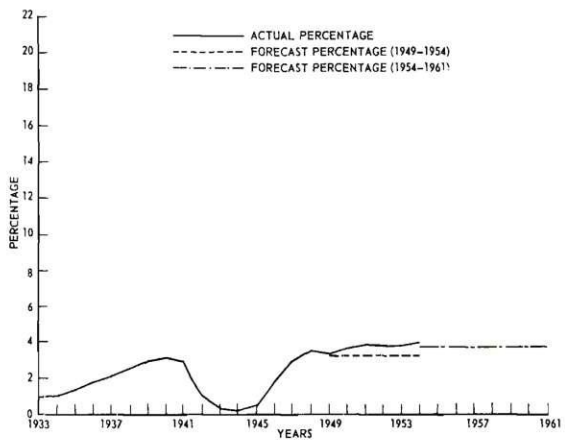


Figure 35. Percentage of Residential Non-Farm Constructions to GNP.

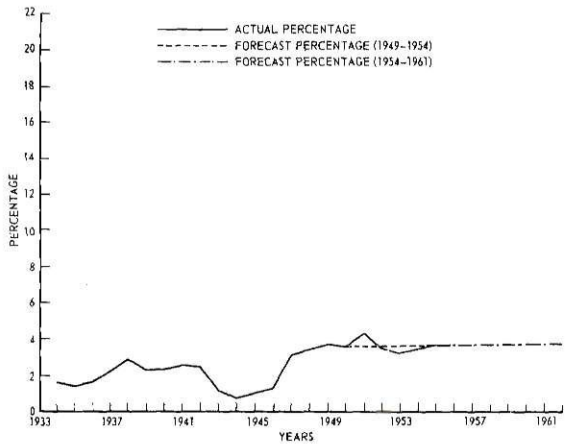


Figure 36. Percentage of all Other Construction to GNP.

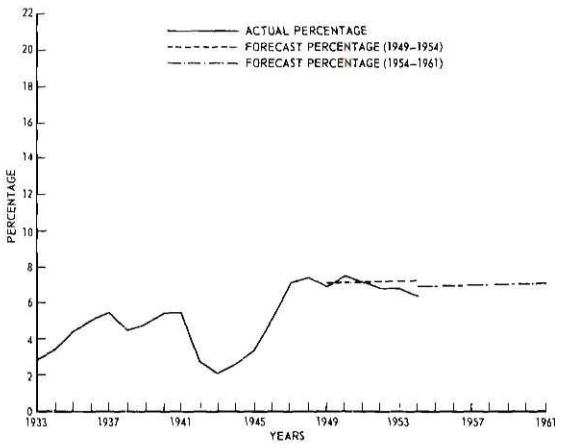


Figure 37. Percentage of Producers Durable Equipment to GNP.

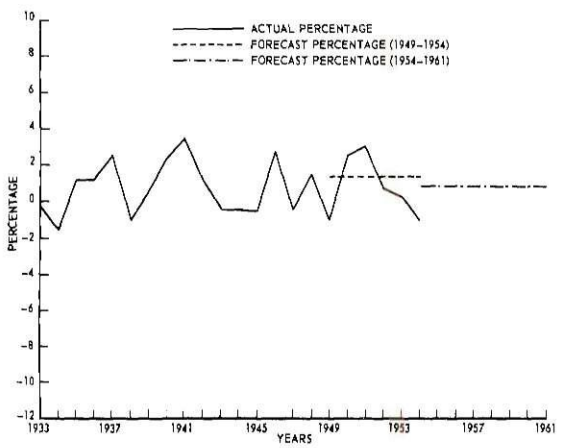


Figure 38. Percentage of Change in Business Inventories to GNP.

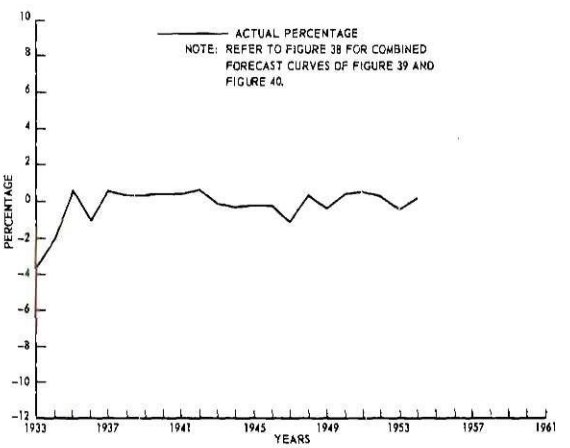


Figure 39. Percentage of Change in Farm Inventories to GNP.

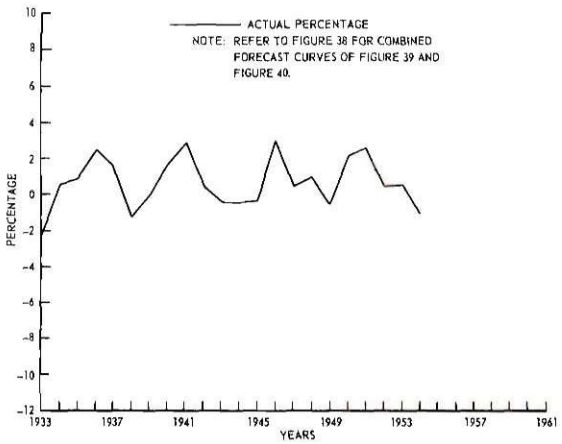


Figure 40. Percentage of Change in Non-Farm Inventories to GNP.

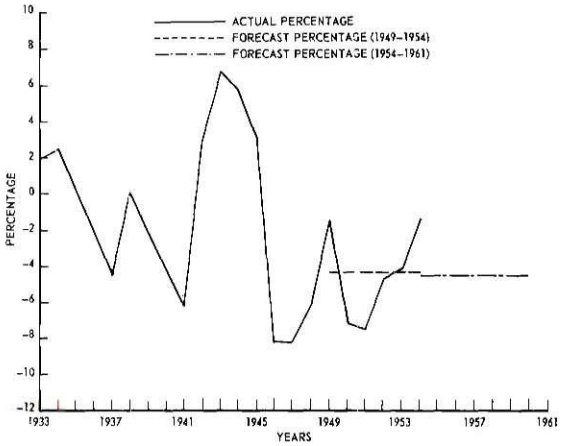


Figure 41. Percentage of Excess of Business Earnings to GNP.

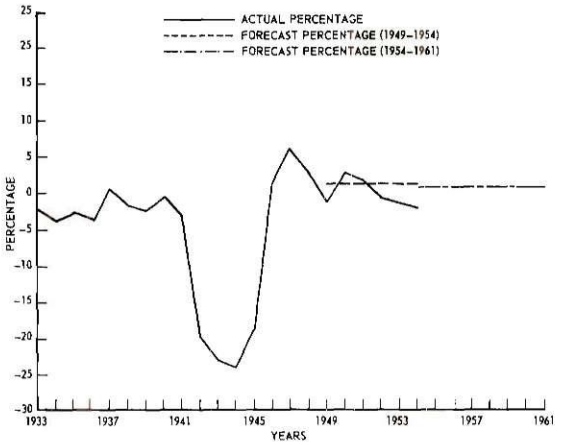


Figure 42. Percentage of Excess of Government Receipts to GNP.

(1). Capital consumption allowances (Figure 8). This percentage was high and decreasing in the thirties due to the fact that the GNP was much lower than before the depression and that allocations of money were still being written off by business. This percentage reached its lowest ebb during the war years of the early forties. The GNP had greatly increased then, and the investment in non-military construction and equipment was at a minimum.

The late 1940's revealed that industry had begun the anticipated post-war expansion. Large quantities of construction and equipment were built and the capital consumption allowance should begin to increase. Approximation for this percentage change during the next five years will be a straight line with a slope of plus one percent. (It is obvious that this approximation must be changed from time to time.)

(2). Net national product (Figure 9). Since this curve is the inverse of Figure 8, it will have a slope of minus one percent for a period of five years.

All items depending upon or related to capital consumption allowances or the net national product will have percentages varying in the same manner. An analysis of the curves related to capital consumption allowances and net national product illustrates the fact that the remaining items are following this linear relationship.

(3). Indirect tax and non-tax liability (Figure 10). This curve has had a relatively small fluctuation over the past years and will be

approximated by a constant percentage. It is a reasonable assumption that if no changes are made in existing tax laws this percentage should remain approximately constant.

(4). National income (Figure 11). This percentage will vary as the net national product described above.

(5). Business transfer payments (Figure 12). By virtue of the small fluctuations in business transfer payments a constant percentage will be used.

(6). Corporate profits tax liability (Figure 13). This percentage will vary as the gross private domestic investment since the country will be becoming more of "big-business" nation.

(7). Contributions for social insurance (Figure 14). This percentage has been almost constant for the past 12 years and will be approximated by a constant.

(8). Personal income (Figure 15). This percentage will vary as the net national product described above.

(9). Undistributed corporate profits (Figure 16). This percentage will vary as the net national product described above.

(10). Net interest paid by government (Figure 17). This percentage will be a constant.

(11). Government transfer payments (Figure 18). This percentage will be a constant.

(12). Federal taxes (Figure 19). This percentage will vary as the net national product.

(13). State and local taxes (Figure 20). This percentage will vary as the net national product.

(14). Personal tax and non-tax payments (Figure 21). This percentage will vary as the net national product.

(15). Disposable personal income (Figure 22). This percentage will be approximated as a constant.

(16). Personal savings (Figure 23). This percentage will be approximated as a constant.

(17). Durable goods (Figure 24). This percentage will be approximated as a constant.

(18). Non-durable goods (Figure 25). This percentage will be approximated as a constant.

(19). Services (Figure 26). This percentage will be approximated as a constant.

(20). Government institutions. No data were available. This item was estimated at forty percent of personal savings.

(21). Private institutions. No data were available. This item was estimated at sixty percent of personal savings.

(22). National security (Figure 27). This percentage will be approximated by a decreasing variable.

(23). Other (Figure 28). This item refers to federal

expenditures other than national security. This percentage will be approximated by a decreasing variable.

(24). State and local expenditures (Figure 29). This percentage will be approximated by a decreasing variable.

(25). Federal expenditures (Figure 30). This percentage will be approximated by a decreasing variable.

(26). Government purchases of goods and services (Figure 31). This percentage will be approximated by a decreasing variable.

(27). Personal consumption expenditures (Figure 32). Since the items affecting these expenditures are a constant percentage, this item also must be constant.

(28). Gross private domestic investment (Figure 33). This percentage will be approximated by an increasing variable.

(29). New construction (Figure 34). This percentage will be approximated by an increasing variable.

(30). Residential non-farm (Figure 35). This percentage will be approximated by an increasing variable.

(31). Other (Figure 36). This percentage will be approximated by an increasing variable.

(32). Producers' durable equipment (Figure 37). This percentage will be approximated by an increasing variable.

(33). Change in business inventories (Figure 38). This percentage will be approximated by an increasing variable.

(34). Farm (Figure 39). This percentage will be approximated by an increasing variable.

(35). Non-farm (Figure 40). This percentage will be approximated by an increasing variable.

Farm and non-farm have complex relationships with other items and will be eliminated from the model as they are relatively insignificant. However, the change in business inventories will be considered as a constant ratio. This item is the sum of the farm and non-farm items. An approximation to the total of two items is much easier than the approximation of each item.

(36). Business investment in government (Figure 41). This percentage will be zero during times of expansion since private business is interested in investment of all its funds plus the investment of as much funds as it can borrow. For purposes of forecasting as used in this analog, this percentage will be zero.

(37). Government investment in business (Figure 42). The government will have an excess of receipts during times when there is a reduction in the expenditures for goods and services. For short term purposes, this item will be considered to be a constant.

Some of the above items are explained in greater detail than others since many of the latter items are but components of the former items as shown in the identities for the model in Table 2.

A Discussion of the Results of Percentage Forecasting of the Spending and Income Items (Experiment 1). --The estimated percentages of spending and income items to GNP (see Figure 8 through Figure 42) for 1950 were close to the actual. Several of these curves were good estimates for the entire five year period. However, due to the Korean War many of the actual percentages reflected quite similar changes to those appearing during World War II, although not as drastic changes.

It is easily seen from an analysis of the curves that the basic reasoning behind an approach of using percentages of GNP is sound. The new values for the system parameters are given in Appendix I, Part III. It is anticipated that Experiment 2 will produce more accurate forecasts for income and spending items.

It is interesting to note that, as a result of the Korean War, the gross private domestic investment (Figure 33) rose rather than fell. This is in contrast to World War II. New construction (Figure 34) and excess of business investment (Figure 41) both also increased. A reasonable answer to these events is that a small war can stimulate expansion and good business in general, while an "all-out" war will definitely tend to stifle business expansion and contraction.

Analog Computer Analysis (Experiment 1). --The curves obtained from the pure exponential estimate of the GNP are shown in Figure 43 through Figure 49. These curves were not as accurate as anticipated. Therefore, the forcing function of the GNP was changed to include a cyclical

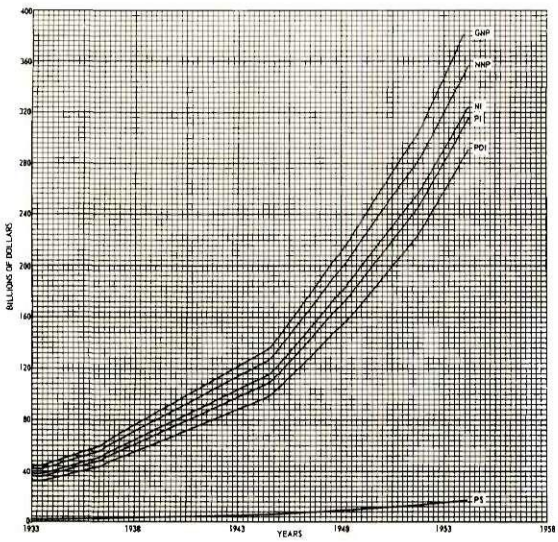


Figure 43. Gross National Product, Series A1.

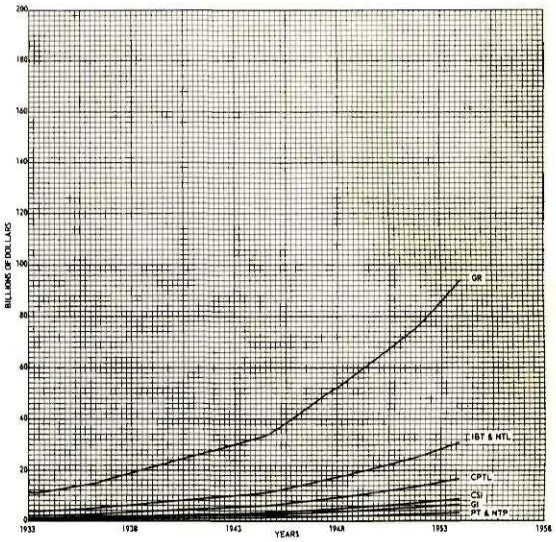


Figure 44. Government Receipts, Series A.

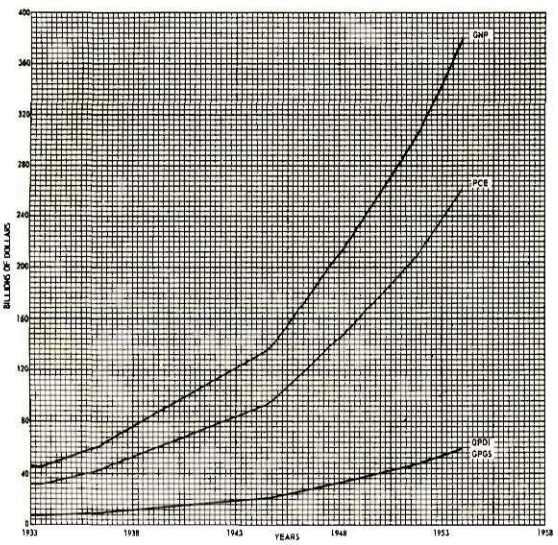


Figure 45. Gross National Product, Series A2.

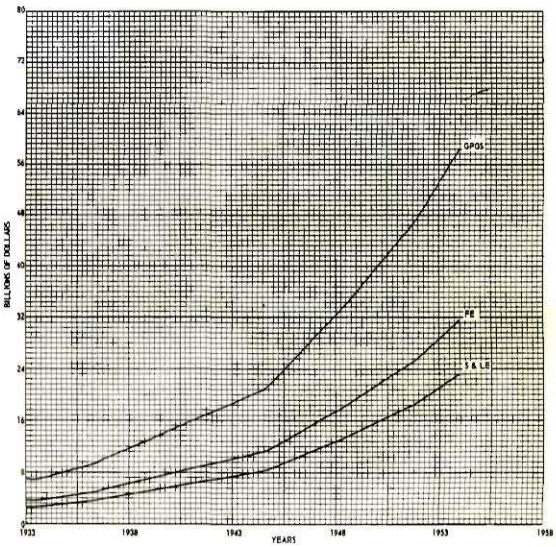


Figure 46. Government Purchases of Goods and Services, Series A.

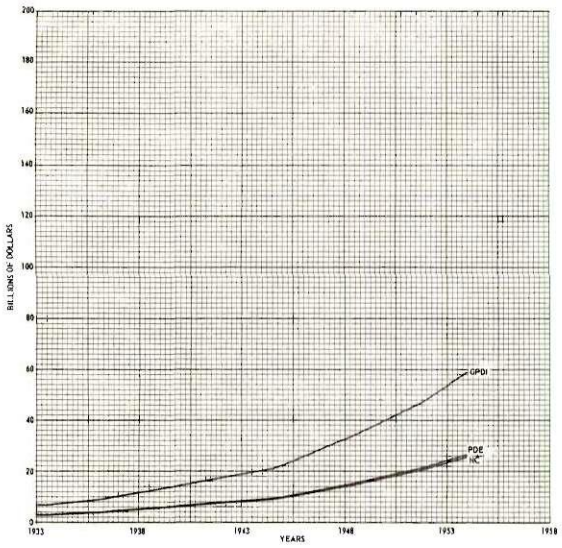


Figure 47. Gross Private Domestic Investment, Series A.

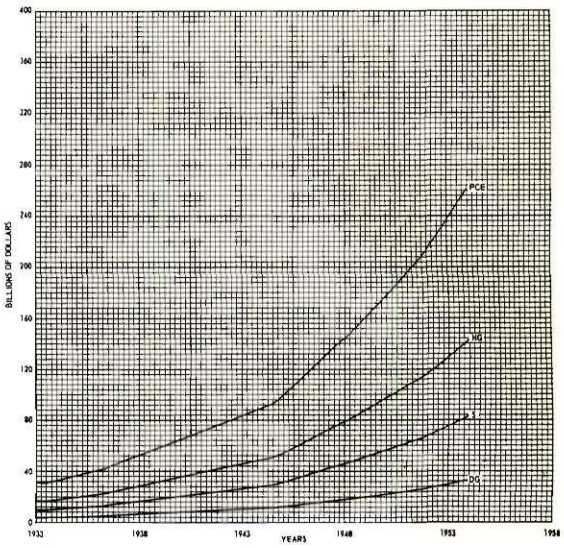


Figure 48. Private Business, Series A.

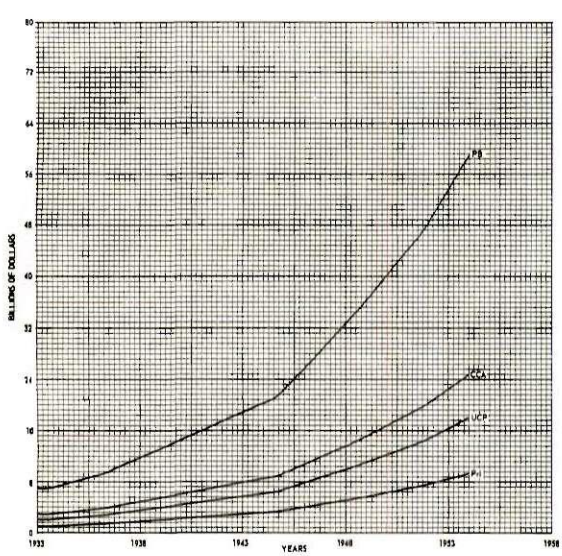


Figure 49. Personal Consumption Expenditures, Series A.

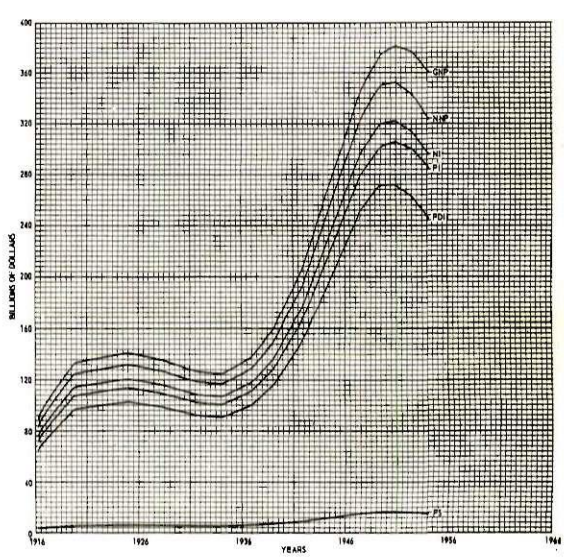


Figure 50. Gross National Product, Series B1.

component. (The breaks in the curve are common to function generator curves since the curve is composed of many straight line segments.)

The last series of experiments for Experiment 1 were conducted with the GNP containing this cyclical component. By comparing the actual spending and income values with the estimated spending and income values for various items (Figure 50 through Figure 56), it was determined that this method of forecasting was reasonably reliable. While performing Experiment 1 on the computer, several changes were made in the electronic analog computer diagram of Figure 4. Also a loading effect on the potentiometers was observed when comparing various readings. This loading affected only those curves in Figure 43 through Figure 49 which were recorded directly from the output of the potentiometer. The loading effect caused an error of approximately five percent. This loading effect was corrected in all later experiments by the method illustrated in Figure 57.

It is believed that this method of forecasting is basically sound and can be used with reasonable success.

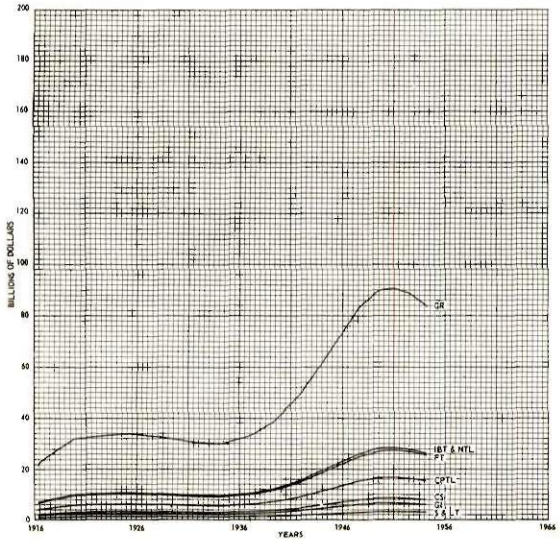


Figure 51. Government Receipts, Series B.

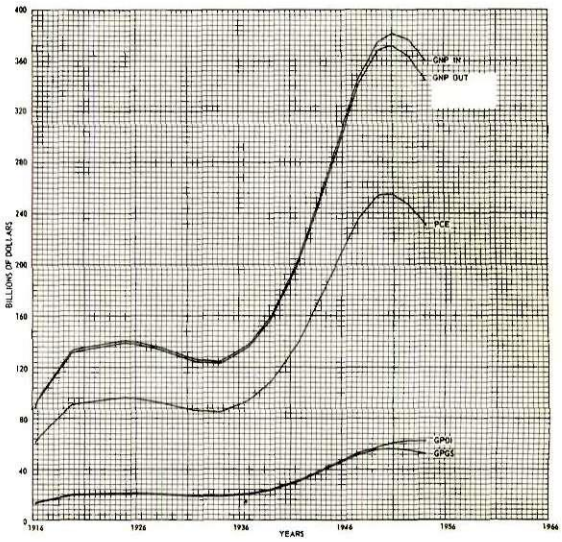


Figure 52. Gross National Product, Series B2.

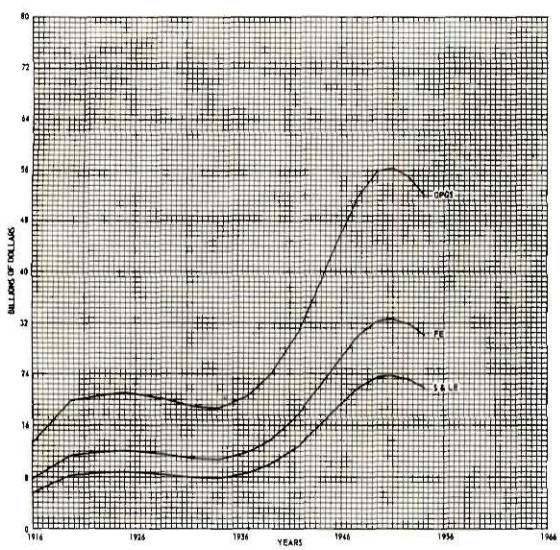


Figure 53. Government Purchases of Goods and Services, Series B.

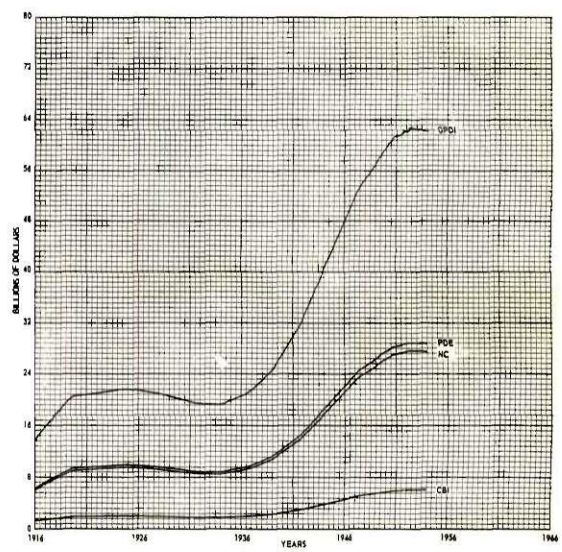


Figure 54. Gross Private Domestic Investment , Series B.

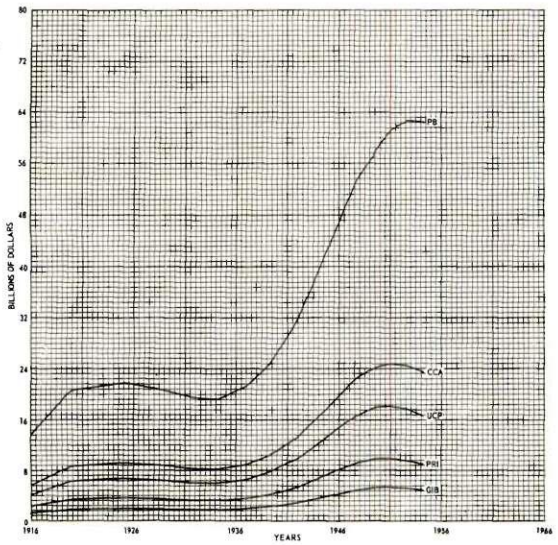


Figure 55. Private Business, Series B.

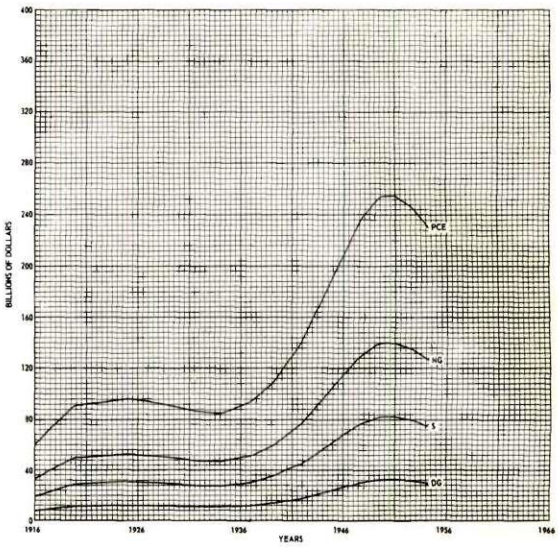
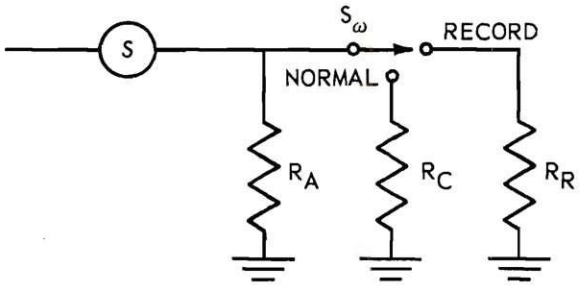


Figure 56. Personal Consumptions Expenditures, Series B.

TO AVOID LOADING WHEN RECORDING FROM THE OUTPUT OF POTENTIOMETERS, THE FOLLOWING CIRCUITRY WAS ADDED AT READ-OUT POINTS TO FIGURE 4.



S_ω – SWITCH
S – POTENTIOMETER
R_A – AMPLIFIER INPUT RESISTANCE
R_C – COMPENSATING RESISTOR
R_R – RECORDER INPUT RESISTANCE
$R_R = R_C = R_A$

Figure 57. Potentiometer Loading Effect.

CHAPTER V

A DISCUSSION OF THE EMPIRICAL RELATIONSHIPS USED AND OF THE RESULTS OBTAINED IN THE ELECTRONIC ANALOG (EXPERIMENT 2)

Gross National Product. --In Experiment 1 the exponential curve with the cyclical component proved to produce a closer "fit" to the actual curve than did the exponential curve alone. In Experiment 2 the gross national product (GNP) was also approximated by an exponential curve with a cyclical component. Table 30 shows the data used in obtaining the least squares curve for the GNP using a logarithmic transformation for the period 1914 - 1954. This table also compares the actual data with the estimated least squares curve. Table 31 shows the sine wave component to be added to the least squares estimate for the period 1916 - 1954. The new GNP curve is shown in Figure 58 with the plus and minus two sigma limits computed from the logarithmic transformation (see Table 32). Note that from 1916 to 1961 there are two points outside of the limits. This is the expected number which will fall outside the limits since we expect five percent of the points to be outside the limits.

Spending and Income Items. --The assumptions used in determining the

Table 30. Calculation of Least Squares Exponential Curve of GNP (1914 - 1954) Using a Logarithmic Transformation

Year	Log GNP*	t	t^2	t Log GNP
1914	1.6128	-20	400	-32.2560
1915	1.6415	-19	361	-31.1885
1916	1.7067	-18	324	-30.7206
1917	1.7803	-17	289	-30.2651
1918	1.8519	-16	256	-29.6304
1919	1.8893	-15	225	-28.3395
1920	1.9400	-14	196	-27.1600
1921	1.8727	-13	169	-24.3451
1922	1.8893	-12	144	-22.6716
1923	1.9415	-11	121	-21.3565
1924	1.9576	-10	100	-19.5760
1925	1.9841	- 9	81	-17.8569
1926	2.0033	- 8	64	-16.0264
1927	2.0120	- 7	49	-14.0840
1928	2.0198	- 6	36	-12.1188
1929	2.0187	- 5	25	-10.0935
1930	1.9595	- 4	16	- 7.8380
1931	1.8825	- 3	9	- 5.6475
1932	1.7672	- 2	4	- 3.5344
1933	1.7482	- 1	1	- 1.7482
1934	1.8129	0	0	0
1935	1.8603	1	1	1.8603
1936	1.9175	2	4	3.8350
1937	1.9581	3	9	5.8743
1938	1.9304	4	16	7.7216
1939	1.9595	5	25	9.7975
1940	2.0026	6	36	12.0156
1941	2.0997	7	49	14.6979
1942	2.2017	8	64	17.6136
1943	2.2844	9	81	20.5596
1944	2.3251	10	100	23.2510
1945	2.3296	11	121	25.6256
1946	2.3206	12	144	27.8472
1947	2.3659	13	169	30.7567
1948	2.4104	14	196	33.7456

Table 30. (Continued)

Year	Log GNP*	t	t^2	t Log GNP
1949	2.4104	15	225	36.1560
1950	2.4548	16	256	39.2768
1951	2.5159	17	289	42.7703
1952	2.5378	18	324	45.6804
1953	2.5611	19	361	48.6609
1954	2.5563	20	400	51.1260
Totals	84.3031	0	5740	112.4149

*Refer to Table 3 through Table 24 for dollar values of GNP.

Log GNP = 2.(5617 + .01958t, t = 0 in 1934

GNP = 113.81 $(1.0461)^t$

Table 31. Comparison of Estimated Exponential Least Squares Data, Actual Data, and Estimated Exponential Plus Cyclical Component (1916 - 1954) Using a Logarithmic Transformation

Year	Actual Log GNP	Log Difference	Estimated Log GNP	Sine Component	Estimated Log GNP Plus Sine Component
1916	1.7067	-0.0029	1.7038	0	1.7038
1917	1.7803	-0.0570	1.7233	0.0358	1.7591
1918	1.8519	-0.1090	1.7429	0.0697	1.8126
1919	1.8893	-0.1268	1.7625	0.0994	1.8619
1920	1.9400	-0.1579	1.7821	0.1235	1.9056
1921	1.8727	-0.0710	1.8017	0.1402	1.9419
1922	1.8892	-0.0681	1.8212	0.1489	1.9701
1923	1.9415	-0.1007	1.8408	0.1489	1.9897
1924	1.9476	-0.0972	1.8604	0.1402	2.0006
1925	1.9841	-0.1041	1.8800	0.1235	2.0035
1926	2.0033	-0.1037	1.8996	0.0994	1.9990
1927	2.0120	-0.0929	1.9191	0.0697	1.9880
1928	2.0198	-0.0811	1.9387	0.0345	1.9745
1929	2.0187	-0.0604	1.9583	0	1.9583
1930	1.9595	0.0184	1.9779	-0.0358	1.9421
1931	1.8825	0.0115	1.9975	-0.0697	1.9278
1932	1.7672	0.2498	2.0170	-0.0994	1.9176
1933	1.7482	0.2884	2.0366	-0.1235	1.9131
1934	1.8129	0.2433	2.0562	-0.1402	1.9160
1935	1.8603	0.2154	2.0757	-0.1489	1.9268
1936	1.9175	0.1778	2.0953	-0.1489	1.9464
1937	1.9581	0.1568	2.1149	-0.1402	1.9747
1938	1.9304	0.2041	2.1345	-0.1235	2.0110
1939	1.9595	0.1946	2.1541	-0.0994	2.0547
1940	2.0026	0.1711	2.1737	-0.0697	2.1040
1941	2.0997	0.0953	2.1932	-0.0358	2.1574
1942	2.2017	0.0111	2.2128	0	2.2128
1943	2.2844	-0.0520	2.2324	0.0358	2.2682
1944	2.3251	-0.0731	2.2520	0.0697	2.3217
1945	2.3296	-0.0580	2.2716	0.0994	2.3710
1946	2.3206	-0.0295	2.2911	0.1235	2.4146

Table 31. (Continued)

Year	Actual Log GNP	Log Difference	Estimated Log GNP	Sine Component	Estimated Log GNP Plus Sine Component
1947	2.3659	-0.0552	2.3107	0.1402	2.4509
1948	2.4104	-0.0801	2.3303	0.1489	2.4792
1949	2.4104	-0.0605	2.3499	0.1489	2.4988
1950	2.4548	-0.0853	2.3695	0.1402	2.5097
1951	2.5159	-0.1269	2.3890	0.1235	2.5125
1952	2.5378	-0.1292	2.4086	0.0994	2.5080
1953	2.5611	-0.1329	2.4282	0.0697	2.4979
1954	2.5563	-0.1085	2.4478	0.0358	2.4830

$$\text{Log GNP} = 2.05617 + .01958t + 0.15 \sin\left(\frac{\pi}{13}\right)t, \quad t = 0 \text{ in } 1934$$

$$\text{GNP} = (113.81)\,(1.0461)^{t}\,(1.4125)^{\sin\left(\frac{\pi}{13}\right)t}$$

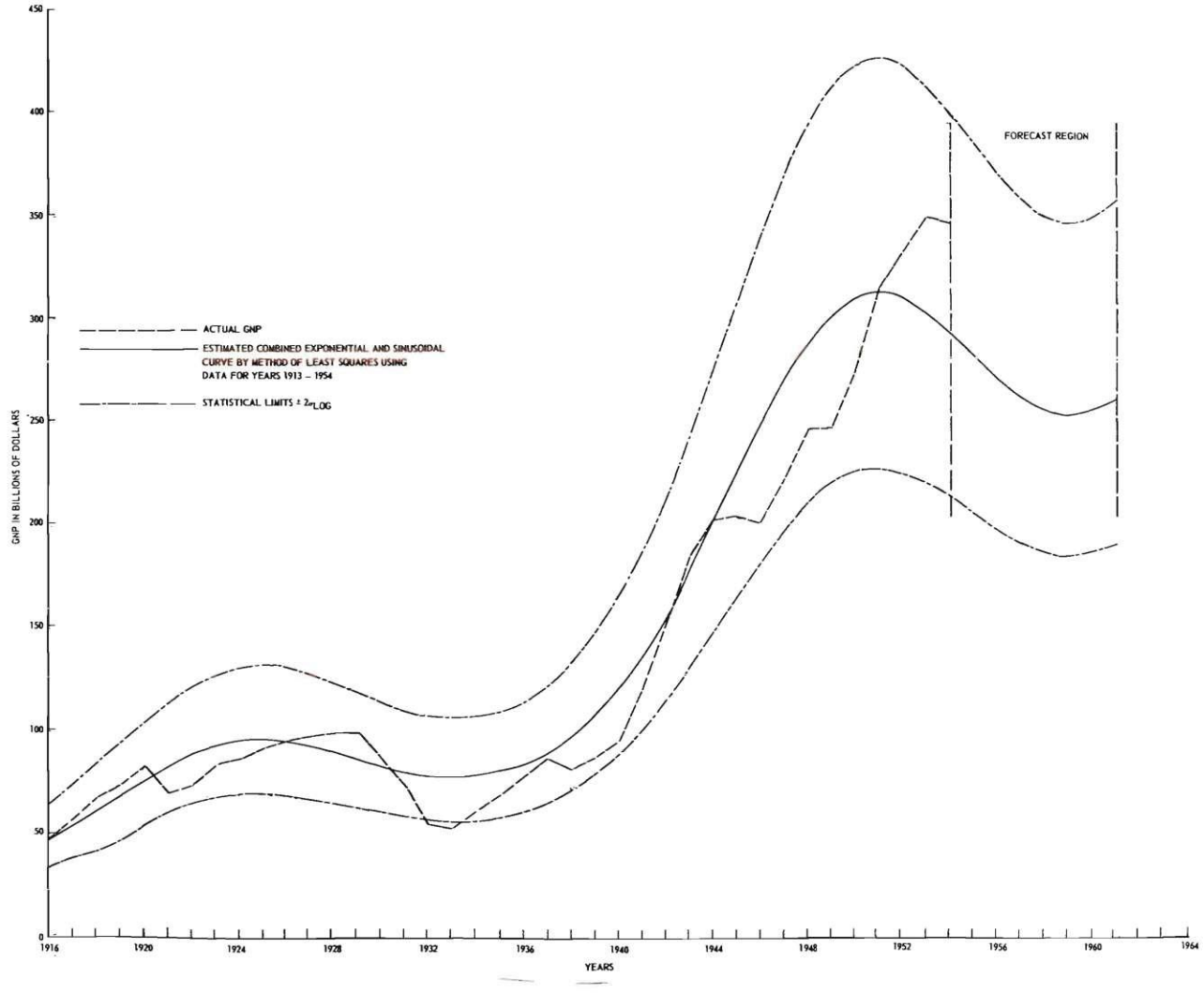


Figure 58. Fitting a Combined Exponential and Sinusoidal Curve to GNP (1916-1954).

Table 32. Ninety-five Percent Confidence Limits for GNP Obtained from Logarithmic Transformation

Year	-2 Sigma*	Log & Sine Estimate *	+2 Sigma*
1916	37.02	50.56	69.05
1917	42.04	57.43	78.45
1918	47.56	64.95	88.72
1919	53.27	72.76	99.38
1920	58.91	80.47	109.90
1921	64.05	87.48	119.50
1922	68.35	93.35	127.50
1923	71.50	97.66	133.40
1924	73.33	100.01	136.80
1925	73.81	100.10	138.90
1926	73.05	99.31	136.30
1927	71.35	99.28	133.10
1928	69.04	94.30	128.80
1929	66.51	90.85	124.10
1930	64.08	87.52	119.50
1931	62.00	84.68	115.70
1932	60.56	82.72	113.00
1933	59.94	81.87	111.80
1934	60.34	82.42	112.60
1935	61.86	84.49	115.40
1936	64.72	88.39	120.70
1937	69.07	94.34	128.90
1938	75.10	102.60	140.10
1939	83.04	113.40	154.90
1940	93.03	127.10	173.60
1941	105.20	143.70	196.20
1942	119.50	163.20	222.90
1943	135.80	185.50	253.30
1944	153.60	209.80	286.50
1945	172.00	235.00	320.90
1946	190.20	259.80	354.90
1947	206.80	282.40	385.70
1948	220.70	301.50	411.70
1949	230.90	315.40	430.70

Table 32. (Continued)

Year	−2 Sigma*	Log & Sine Estimate*	+2 Sigma*
1950	236.80	323.40	441.70
1951	238.30	325.50	444.60
1952	235.80	322.10	440.00
1953	230.30	314.70	429.80
1954	223.00	304.50	416.00
1955**	214.80	293.40	400.70
1956**	206.90	282.60	386.00
1957**	200.20	273.40	373.50
1958**	195.60	267.10	364.90
1959**	193.60	264.40	361.10
1960**	194.80	266.10	363.50
1961**	199.60	272.90	372.70

*All values are in billions of dollars.

**These years were forecast using the 1916 - 1954 data.

percentage values of GNP in Experiment 1 were satisfactory for the years since 1946. Values for the spending and income items prior to 1946 are in error because some of the percentages have undergone major changes in their relationship with GNP over the past 40 years. Since it was only the immediate future that was of concern in this study, the percentages are recomputed (see Figure 8 through Figure 42) and new values are determined for the potentiometers (see Appendix I, Part II and Part III). If such a model were to be actually used as a method of forecasting, these percentages would be re-calculated at the end of each reporting period in order to make as much use as possible of any current trends. It is of interest to note from the figures that some of the percentages are varying with time. In the electronic analog, an operational relay was set to begin to operate at t = 1954. This relay initiated the resolver which provided the varying percentage.

A Discussion of the Results of Experiment 2.--It is impossible to determine the accuracy of the estimates for the period 1955 through 1961 since none of the data is available for any of the forecast years. It is of interest to note from Figure 58 that the forecast lowest point in our economy will be 1959 and then a rapid increase will begin to occur. The curves which were determined from this model of the economy of the United States and plotted by the analog computer are shown in Figure 59 through Figure 65. These curves are the forecast figures for the various components of spending and income in the United States.

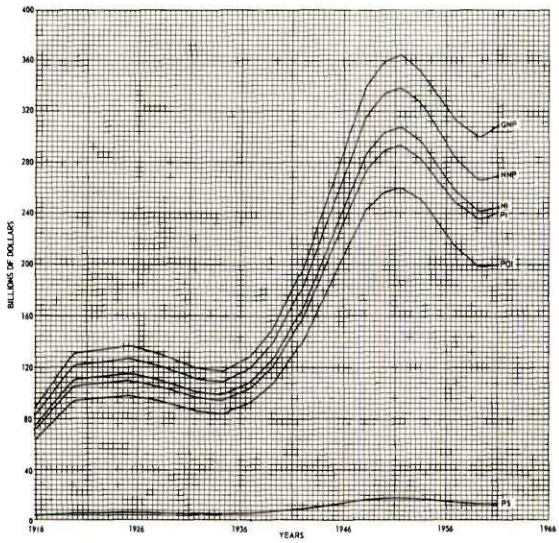


Figure 59. Gross National Product, Series C1.

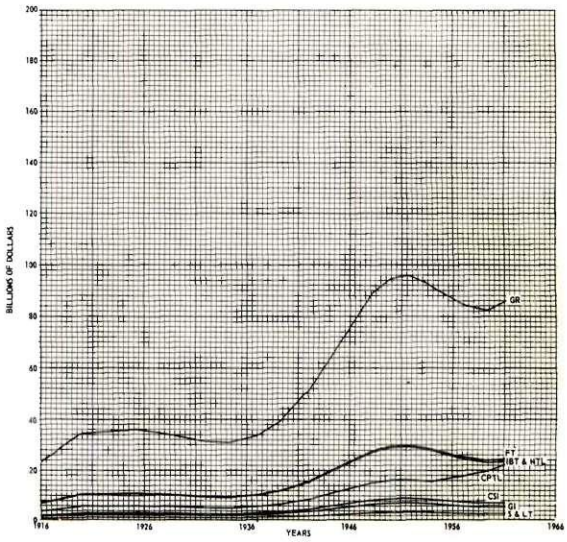


Figure 60. Government Receipts, Series C.

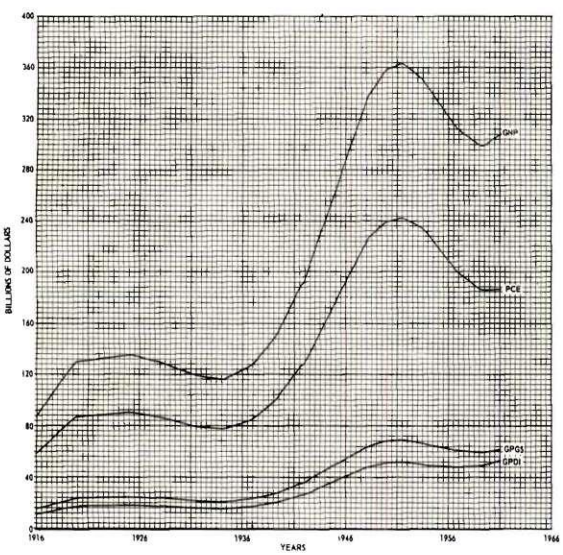


Figure 61. Gross National Product, Series C2.

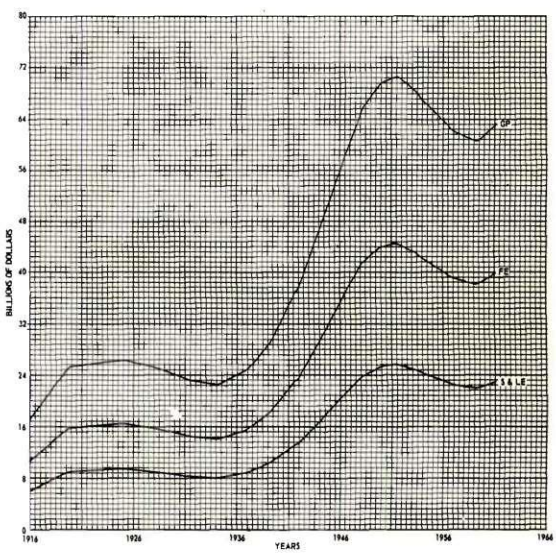


Figure 62. Government Purchases of Goods and Services, Series C.

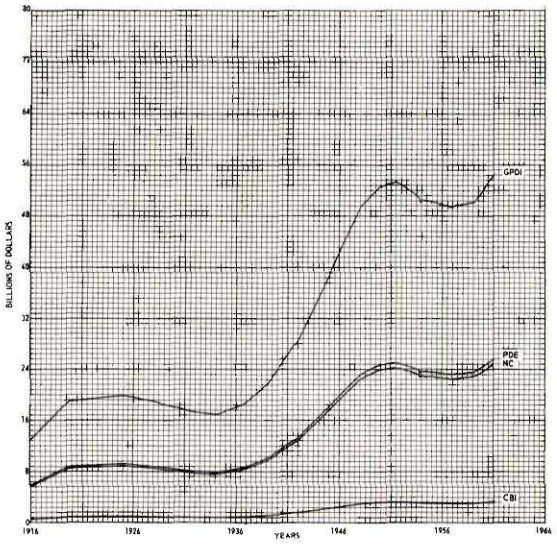


Figure 63. Gross Private Domestic Investment, Series C.

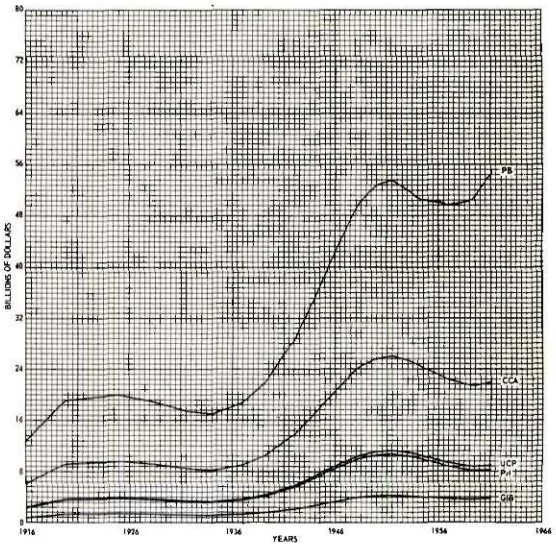


Figure 64. Private Business, Series C.

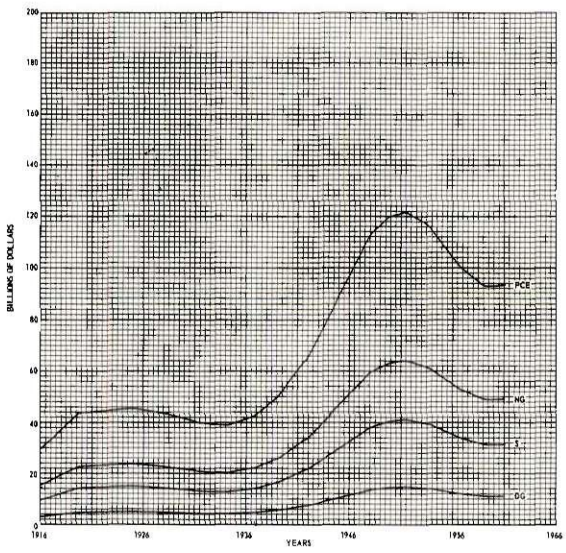


Figure 65. Personal Consumptions Expenditures, Series C.

In this experiment certain cause-and-effect relationships were studied with reference to producers' durable equipment (PDE). The increments of variations studied would be: for example, in 1954, plus and minus one percent of GNP corresponds to plus and minus 3.6 billion dollars, plus and minus two percent of GNP corresponds to plus and minus 7.2 billion dollars, plus and minus three percent of GNP corresponds to plus and minus 10.8 billion dollars. The results of these cause-and-effect studies are shown in Figure 66 through Figure 71. It will be noted that these figures are plotted over the 15-year period of 1946 to 1951. Producers' durable equipment was observed while varying the amount of dollars going to the following items:

Private institutions. This item was varied in increments of plus and minus one and plus and minus two percent of GNP. From Figure 66 the expected change in PDE can be determined. The effect is that if personal savings were invested more with private business, there would be more investment in PDE. This amount can be determined in quantitative terms from Figure 66.

Capital consumption allowances. This item was varied in increments of plus and minus one and plus and minus three percent of GNP (Figure 67). The result obtained indicates that if depreciation laws are changed there will be more investment in PDE; also, the converse is true.

Personal tax and non-tax payments. This item was varied in

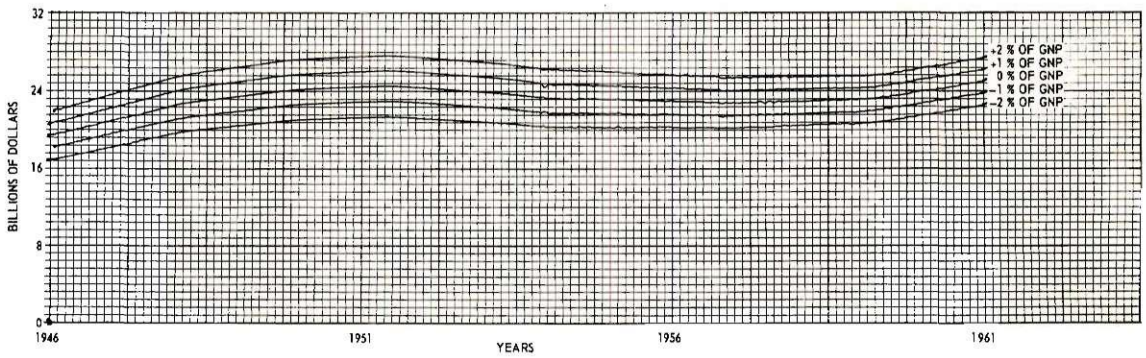


Figure 66. Effect of Varying Private Institutions on Producers Durable Equipment.

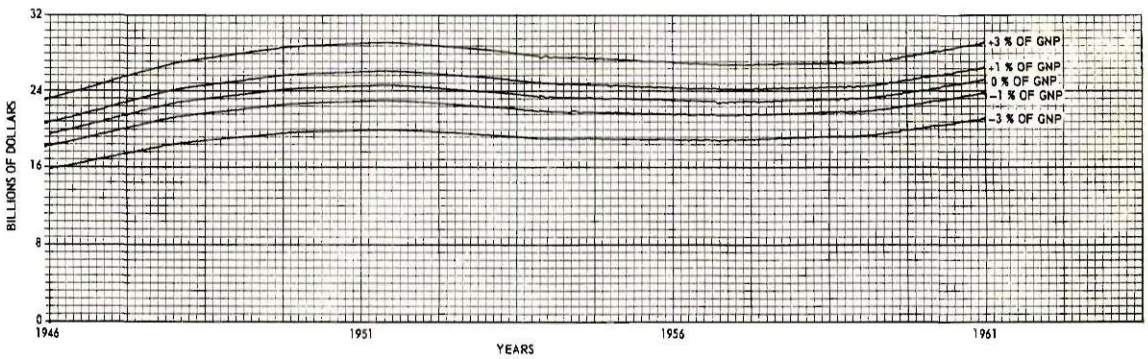


Figure 67. Effect of Varying Capital Consumption Allowances on Producers Durable Equipment.

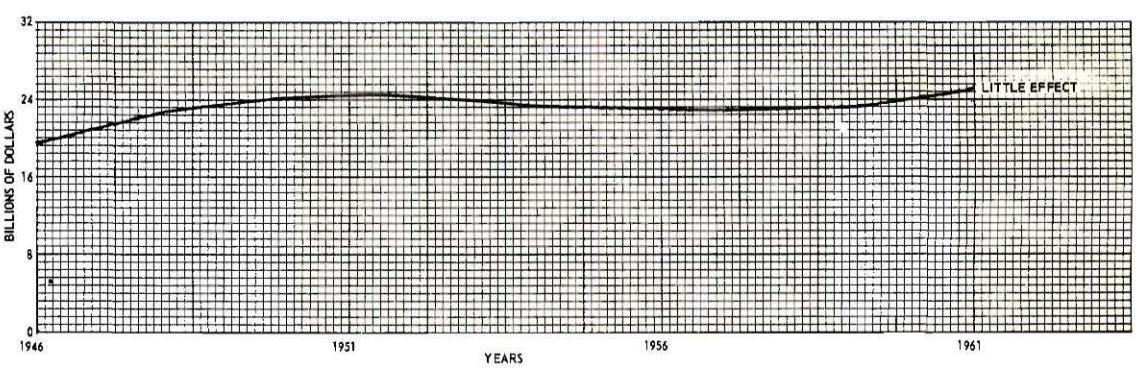


Figure 68. Effect of Varying Personal Tax and Non-Tax Payments on Producers Durable Equipment.

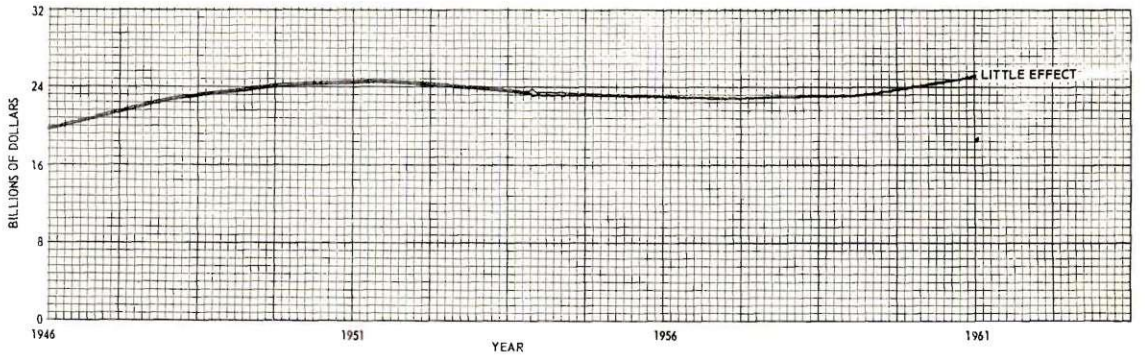


Figure 69. Effect of Varying Indirect Business Tax and Non-Tax Liability on Producers Durable Equipment.

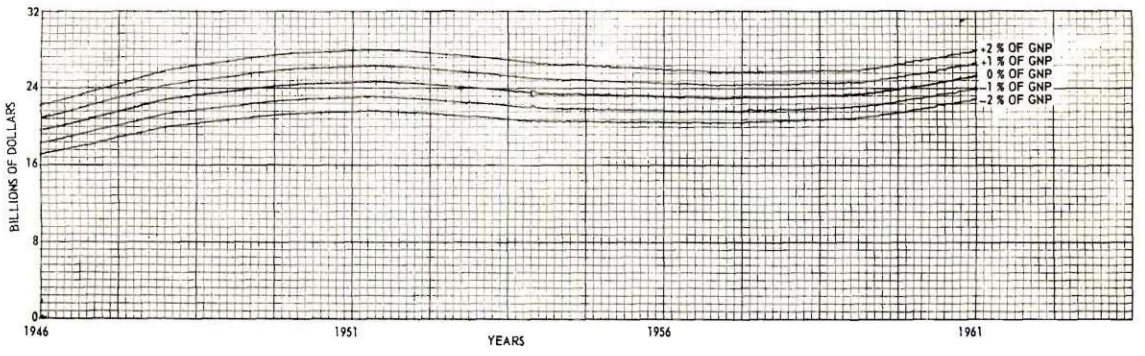


Figure 70. Effect of Varying Undistributed Corporate Profits on Producers Durable Equipment.

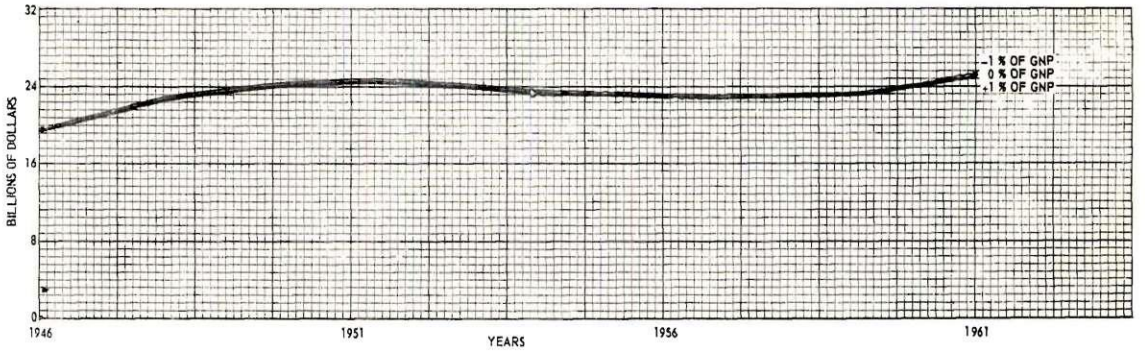


Figure 71. Effect of Varying Corporate Profits Tax Liability on Producers Durable Equipment.

increments of plus and minus one and plus and minus two percent of GNP (Figure 68). The results show that this item has little effect on PDE.

Indirect business taxes and non-tax liability. This item was varied in increments of plus and minus one and plus and minus three percent of the GNP (Figure 69). This item has little effect on expenditures for PDE.

Undistributed corporate profits. This item was varied in increments of plus and minus one and plus and minus two percent of the GNP (Figure 70). This result indicates that if corporations retain more of the profits, there will be more investment in PDE.

Corporate profits tax liability. This item was varied in increments of plus and minus one and plus and minus two percent of GNP (Figure 71). This result shows how much more money will be invested in PDE by decreasing corporate taxes.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Conclusions.--The following conclusions have been reached from the results obtained in this study:

(1). An electronic analog can be developed as a dynamic model of an economic system and used as an aid in forecasting the behavior of a macro-economic system. Extreme care must be exercised in the determination of the mathematical shape of the gross national product (GNP) which is the exponential forcing function governing the operation of the analog.

(2). The use of percentages of spending and income items to the GNP can be applied as a method of breaking-down the GNP into its minor components.

(3). The method by which the percentage of spending and income items to the GNP is varying can be determined on the analog computer, partially eliminating the need for complicated mathematical analysis.

(4). The results of changes in any components of the GNP considered as independent variables on some other components of the GNP considered as dependent variables can be determined merely by manipulating a few dials and reading either a number or a graph.

(5). Any curve of GNP which is believed to follow a certain trend can be placed in the computer and an analysis of its variations can be observed. The only requirement for the GNP input is that a graph can be drawn of the function. Any statistical limits can be applied along with the GNP by utilizing two additional function generators. The limits will then appear on the graph of any item under observation.

(6). Dynamic models of this type can be used as a training aid in some non-physical areas as well as physical areas.

Recommendations. --The following recommendations are made as a result of this study:

(1). It is recommended that improvements be made on the model to include more feed-back and feed-forward relationships.

(2). It is recommended that a further analysis of a somewhat similar nature be undertaken. For example, it is possible to expand the block "private business" to include all industries. Then one can expand a specific industry into the companies composing the industry. From this analysis studies can be made of the complex inter-company and inter-industry relationships in mathematical terminology.

(3). It is recommended that a model similar to the one discussed in this study be used in class room demonstrations in classes of quantitative economics and of system simulation.

APPENDIX

APPENDIX I

PART I

Method of Determining Potentiometer Settings (Experiment 1)

$G = GNP$

$CCA = 0.065\ G$* (S28)**

$$NNP = \frac{0.935\ G}{1.000\ G} \quad (S29)$$

$$NI = 0.852\ G = \frac{0.852}{0.935} NNP = 0.910\ NNP \quad (S25)$$

$$BTP = 0.003\ G = \frac{0.003}{0.935} NNP = 0.003\ NNP \quad (S24)$$

$$IBT\ \&\ NTL = 0.081\ G = \frac{0.081}{0.935} NNP = 0.087\ NNP \quad (S26)$$

$$CPTL = 0.045\ G = \frac{0.045}{0.852} NI = 0.053\ NI \quad (S17)$$

$$CSI = 0.024\ G = \frac{0.024}{0.852} NI = 0.027\ NI \quad (S20)$$

$$PI / NI = 0.739\ G = \frac{0.749}{0.852} NI = 0.864 \quad (S23)$$

$$UCP = 0.050\ G = \frac{0.050}{0.852} NI = 0.057\ NI \quad (S22)$$

$$PI = (0.739 + 0.046 + 0.019 + 0.003)\ G = 0.807\ G$$

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*Values to right of equal signs were obtained from Figure 8 through Figure 42.

**(Sxx) refers to the specific potentiometer used in the analog. The value adjacent to (Sxx) is the actual potentiometer setting.

$$PDI = 0.729\ G = \frac{0.729}{0.807} PI = 0.903\ PI \quad (S8)$$

$$FT = 0.073\ G = \frac{0.073}{0.807} PI = 0.090\ PI \quad (S12)$$

$$S\ \&\ LT = 0.008\ G = \frac{0.008}{0.807} PI = 0.010\ PI \quad (S13)$$

$$PS = 0.045\ G = \frac{0.045}{0.729} PDI = 0.061\ PDI \quad (S5)$$

$$DG = 0.089\ G = \frac{0.089}{0.729} PDI = 0.120\ PDI \quad (S2)$$

$$NG = 0.380\ G = \frac{0.380}{0.729} PDI = 0.515\ PDI \quad (S3)$$

$$S = 0.225\ G = \frac{0.225}{0.729} PDI = 0.304\ PDI \quad (S6)$$

$$GI = 0.018\ G = \frac{0.018}{0.045} PS = 0.400\ PS \quad (S9)$$

$$PrI = 0.027\ G = \frac{0.027}{0.045} PS = 0.600\ PS \quad (S4)$$

$$PB = CCA + UCP + GIB + PrI = (0.065 + 0.050 + 0.015 + 0.027)\ G = 0.157\ G$$

$$CBI = 0.015\ G = \frac{0.015}{0.157} PB = 0.098\ PB \quad (M1)$$

$$PDE = 0.072\ G = \frac{0.072}{0.157} PB = 0.461\ PB \quad (M4)$$

$$RNF = 0.033\ G = \frac{0.033}{0.157} PB = 0.209\ PB \quad (M3)$$

$$O_2 = 0.036\ G = \frac{0.036}{0.157} PB = 0.232\ PB \quad (M2)$$

$$GR = GI + PT \& NTL + CSI + CPTL + IBT \& NTL$$

$$= G\,(0.018 + 0.008 + 0.074 + 0.024 + 0.045 + 0.081)$$

$$= 0.250\,G$$

$$GTP = 0.047\,G = \frac{0.047}{0.250}\,GR = 0.185\,GR \quad (S10)$$

$$NIPBG = 0.019\,G = \frac{0.019}{0.250}\,GR = 0.075\,GR \quad (S7)$$

$$S \& LE = 0.066\,G = \frac{0.066}{0.250}\,GR = 0.262\,GR \quad (S11)$$

$$GIB = 0.015\,G = \frac{0.015}{0.250}\,GR = 0.060\,GR \quad (S15)$$

$$FE = 0.090\,G = \frac{0.090}{0.250}\,GR = 0.360\,GR \quad (S14)$$

PART II

Method of Determining Potentiometer Settings (Experiment 2)

$G = GNP$

$CCA = 0.072\ G^{*}$ (S28)**

$$NNP = \frac{0.928}{1.000} G \quad (S29)$$

$$NI = 0.846\ G = \frac{0.846}{0.928} NNP = 0.910\ NNP \quad (S25)$$

$$BTP = 0.003\ G = \frac{0.003}{0.928} NNP = 0.003\ NNP \quad (S24)$$

$$IBT\ \&\ NTL = 0.081\ G = \frac{0.081}{0.928} NNP = 0.087\ NNP \quad (S26)$$

$$CPTL = 0.045\ G = \frac{0.045}{0.846} NI = 0.054\ NI \quad (S17)$$

$$CSI = 0.025\ G = \frac{0.025}{0.846} NI = 0.030\ NI \quad (S20)$$

$PI = 0.807 = BTP + PI/NI + NIPBG + GTP$

$PI/NI = (0.807 - 0.003 - 0.015 - 0.041)\ G$

$$PI/NI = 0.748\ G = \frac{0.748}{0.846} NI = 0.883\ NI \quad (S23)$$

$$UCP = 0.032\ G = \frac{0.032}{0.846} NI = 0.038\ NI \quad (S22)$$

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*Values to right of equal signs were obtained from Figure 8 through Figure 42.

**(Sxx) refers to the specific potentiometer used in the analog. The value adjacent to (Sxx) is the actual potentiometer setting.

$$PI = (0.748 + 0.015 + 0.041 + 0.003)\,G = 0.807$$

$$PDI = 0.715\,G = \frac{0.715}{0.807}\,PI = 0.886\,PI \quad (S8)$$

$$FT = 0.082\,G = \frac{0.082}{0.807}\,PI = 0.102\,PI \quad (S12)$$

$$S\ \&\ LT = 0.010\,G = \frac{0.010}{0.807}\,PI = 0.012\,PI \quad (S13)$$

$$PS = 0.051\,G = \frac{0.051}{0.715}\,PDI = 0.071\,PDI \quad (S5)$$

$$DG = 0.085\,G = \frac{0.085}{0.715}\,PDI = 0.119\,PDI \quad (S2)$$

$$NG = 0.355\,G = \frac{0.355}{0.715}\,PDI = 0.498\,PDI \quad (S3)$$

$$S = 0.230\,G = \frac{0.230}{0.715}\,PDI = 0.322\,PDI \quad (S6)$$

$$GI = 0.020\,G = \frac{0.020}{0.051}\,PS = 0.400\,PS \quad (S9)$$

$$PrI = 0.031\,G = \frac{0.031}{0.051}\,PS = 0.060\,PS \quad (S4)$$

$$PB = CCA + UCP + GIB + PrI$$

$$= (0.072 + 0.032 + 0.013 + 0.031)\,G$$

$$= 0.148\,G$$

$$CBI = 0.010\,G = \frac{0.010}{0.148}\,PB = 0.068\,PB \quad (M1)$$

$$PDE = 0.068\,G = \frac{0.068}{0.148}\,PB = 0.458\,PB \quad (M4)$$

$$RNF = 0.034\,G = \frac{0.034}{0.148}\,PB = 0.229\,PB \quad (M3)$$

$$O_2 = 0.036\ G = \frac{0.036}{0.148}\ PB = 0.243\ PB \quad (M2)$$

$$GR = GI + PT\ \&\ NTL + CSI + CPTL + IBT\ \&\ NTL$$

$$= (0.020 + 0.091 + 0.025 + 0.081 + 0.045)\ G$$

$$= 0.263\ G$$

$$GTP = 0.041\ G = \frac{0.041}{0.263}\ GR = 0.158\ GR \quad (S10)$$

$$NIPBG = 0.015\ G = \frac{0.015}{0.263}\ GR = 0.158\ GR \quad (S7)$$

$$S\ \&\ LE = 0.071\ G = \frac{0.071}{0.263}\ GR = 0.271\ GR \quad (S11)$$

$$O_1 = 0.023\ G = \frac{0.023}{0.263}\ GR = 0.088\ GR \quad (S15)$$

$$GIB = 0.013\ G = \frac{0.013}{0.263}\ GR = 0.049\ GR \quad (S15)$$

$$NS = 0.123\ G = \frac{0.123}{0.263}\ GR = 0.467\ GR \quad (S14)$$

PART III

Value of Potentiometers Used in Analog

Potentiometer	Function	Experiment 1	Experiment 2
S1	*	0.032	0.032
S2	DG	0.120	0.119
S3	NG	0.515	0.498
S4	PrI	0.600	0.600
S5	PS	0.061	0.071
S6	S	0.304	0.322
S7	NIPBG	0.075	0.057
S8	PDI	0.903	0.886
S9	GI	0.400	0.400
S10	GTP	0.185	0.158
S11	S & LE	0.262	0.271
S12	FT	0.090	0.102
S13	S & LT	0.010	0.012
S14	NS & O_1	0.360	0.467
S15	GIB	0.060	0.049
S16	*	0.500	0.500
S17	CPTL	0.052	0.054
S18	*	0.225 and 0.114	0.225
S19	*	0.160	0.160
S20	CSI	0.027	0.030
S21	*	0.750	out
S22	UCP	0.057	0.038
S23	PI / NI	0.864	0.883
S24	BTP	0.003	0.003
S25	NI	0.910	0.910
S26	IBT & NTL	0.081	0.087
S27	*	0.032	0.032
S28	CCA	0.065	0.072
S29	NNP	0.935	0.928
M1	CBI	0.098	0.068
M2	O_2	0.232	0.243
M3	RNF	0.209	0.229
M4	PDE	0.461	0.458

*Necessary to perform electrical hook-up.

APPENDIX II

Forecast GNP* (1960 - 2000)

Year	GNP in Billions of Dollars
1960	266.1
1965	366.4
1970	677.7
1975	1020.0
1980	984.3
1985	854.7
1990	1237.1
1995	2239.8
2000	3641.2

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*Values of GNP obtained from the following formula:

$$GNP = (113.81)\,(1.0461)^{t}\,(1.4125)^{\sin\left(\frac{\pi}{13}\right)t}$$

where t = 0 in 1934

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